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Reduction of Formation Damage and Fluid Loss using Nano-sized Silica Drilling Fluids

By

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Abstract

Drilling fluid is an important part of the drilling process. All drilling fluid must have common specifications that enable safe and satisfactory completion of the well. The key challenge in developing a water-based fluid for such operations has been to maintain the stability of key fluid properties such as rheology and fluid loss at higher temperatures. Drilling Fluid represents up to one fifth (15 to 18%) of the total cost of well petroleum drilling.

The main objective of this research work is to reduce the formation damage due to drilling operation by investigating the fluid loss characteristics of water-based mud when nanoparticles are used as fluid loss additives. Three different sizes of silica nanoparticles were used in conducting this experiment in order to determine the nanoparticles size range that yields the minimum filtrate loss. Further experiments were conducted on the best nanoparticle size by studying the relationship between the filtrate volume and nanoparticle concentration to reach the concentration that provides the most filtrate volume reduction at the lowest possible cost. The changes in rheological properties of the mud were also studied along with the fluid loss values. An overall evaluation of drilling fluid technology was performed. The rheological properties and the API filtrate losses of laboratory-prepared water based mud results are presented; and comparative analysis the fluid loss reduction was conducted on silica nanoparticles as fluid loss additive with an industry standard polymer-based fluid loss additive.

In conclusion, we found out that the optimum size of nanoparticles was 5-15 nm (size 1). The most economic and yet effective concentration of nanoparticles is the range between 20% and 30% wt./vol., which lead to a 56% reduction in fluid loss in comparison with the base fluid.

Keywords: Nano material, Nanotechnology, Formation Damage, Nano Drilling Fluids, Smart Fluids, Nano Silica

Introduction

Nanotechnology is the science of handling material at the atomic or molecular level and holds the potential of providing significant advances in technologies for protecting the environment.

Since there are many definitions for nanotechnology exist, the U.S. Environmental Protection Agency (EPA) uses the definition established by the National Nanotechnology Initiative (NNI). The NNI[1] wants nanotechnology to comprise all of the following:

a) Research and technology development at the atomic, molecular, or macromolecular levels, in the length scale of approximately 1-100 nanometer (nm) range in any direction;

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[1] National Nanotechnology Initiative (NNI). 2007. Website. Accessed December 2007. http://www.nano.gov/.

b) Generating and using structures, devices, and systems that have novel properties and functions as a result of their small and/or intermediate size; and
c) Ability to control or manipulate on the atomic scale.

Drilling a well is the first and the most expensive step in the petroleum industry. Expenditures for drilling represent 25% of the total oilfield exploitation cost and are concentrated mostly in exploration and development of well drilling. API (1991) stated that, the drilling fluids represent till one fifth (15 to 18%) of the total cost of well petroleum drilling. Drilling fluids went through major technological evolution, since the first operations performed in the USA, using a simple mixture of water and clays, to complex mixtures of various specific organic and inorganic products used nowadays. These products improve fluid rheological properties and filtration capability.

There are many different types of drilling fluids, each of which has qualities that are uniquely suited to particular situations. Most drilling fluids can be broken up into the categories of ***liquid*** and ***gas based***. Liquid based fluids are usually called drilling mud, and can be further broken down into ***water*** and ***oil based*** (**WBM**, and **OBM**) muds.

Smart fluids: Nano drilling fluids are fluids that contain particles (additives) in nano size. Based on the number of nano-sized additives, it can be categorized as simple nano fluid or advanced nano fluid. Nano fluids with one nano-sized additive are distinct as *simple nano-fluids*, while those with more than one nano-sized additive are defined as *advanced nano fluids*. From functional points of view, a nanomaterial could be single functional or multifunctional. A multifunctional nano-additive can perform several functions in the fluids systems to complete the whole tasks of the fluid with a dramatic reduction in total solids and/or chemical content of a mud and also the overall mud cost. The significantly higher functional ability with a reduction in overall fluid cost in spite of high cost of individual additive is expected to be one of the characteristic features of nano-based smart fluids[2]. It can play a major role in solving some of the most common problems encountered while drilling. These nano-particles have a very high surface area to volume ratio which increases the reactivity of the nano-particles. Due to this fact, the amount of nano-particles required for any application is much less which reduces the cost to a great extent[3].

Nanotechnology in Drilling Operations

Nanotechnology has huge applications in different segments in the oil and gas industry such as in exploration, drilling, completion and work-over, production, and Enhanced Oil Recovery (EOR). It is also integrated in producing equipment that is lighter, more resistant, and stronger such as nanotubes. Nanotubes have many potential applications within the oil industry. They are used to create lighter, stronger, and more corrosion-resistant structural materials in platforms for offshore drilling. Nanotechnology can also be used for oil and gas separation in the reservoir through better understanding of processes at the molecular level. The aim is to separate oil and water more effectively. The applications of nanotechnology in the oil and gas industry will further be described in details here but only for drilling fluid application and formation damage reduction while drilling operations.

[2]Amanullah M., and Al-Tahini A.M., “Nano-Technology Â– Its Significance in Smart Fluid Development for Oil and Gas Field Application”, SPE 126102 presented at the SPE Saudi Arabia Section Technical Symposium and Exhibition, Alkhobar, Saudi Arabia, 09-11 May, 2009.
[3] Subhash N. Shah, Narayan H. Shanker, and Chinenye C. Ogugbue. 2010 .Future Challenges of Drilling Fluids and Their Rheological Measurements, AADE-10-DF-HO-41, presented at the 2010 AADE Fluids Conference and Exhibition held at the Hilton Houston North, Houston, Texas.

Sensoy et. al.[4] showed in their work the benefit of nanomaterial addition to WBM while drilling operations. Their results proved that nanomaterial reduces the Atoka shale permeability by a factor of 5 to 50 Nabhani-Emami[5] summarized most recent advancement in nanotechnology in the oil and gas drilling engineering. These include high fluid loss, wellbore instability, pipe sticking problem and drag reduction.

Damage Reduction and Lost Circulation**:** Abdo- Haneef[6] stated that the prevention of loss of circulation by micro and macro material-based LCM materials showed limited success in these environments. Tailored made nanoparticles with the potential to build structural barriers according to the size and shape of the loss paths are expected to provide effective sealing of the porous and permeable zones, fractured and cavernous formations. Multi-functional nanoparticles owning both sealing and strengthening potential are expected to remove the scope of induced loss of circulation. In this way, this work presents an experimental study showing how the Nano materials can reduce and mitigate the formation damage.

Experimental Methodology

Fluid Preparation Steps

The fluid preparation involved various stages and each had to be carried out in particular order using the same types and concentrations of additives in order to achieve consistent fluid blends for the results to be reliable. Maintaining other independent variables, such as the pH and temperatures of the blends, was also an important step in preparation of the fluid. The additives were added in reference to sample sizes of 350 mL for ease of comparison with equivalent field units.

Caustic soda, soda ash, potassium chloride and barite were weighed out on a high precision lab scale and added to 336ml of water in a Hamilton beach mixer cup. Xanthan Gum polymer was then weighed on the balance and slowly added to the mixer while operating to ensure that the polymer fully dissolves without the formation of any lumps. A pH meter was used to measure the pH while preparing the fluid to ensure that the pH of the fluid was in the range of 9-10 and that the utilized amount of caustic soda is sufficient to bring the pH to an alkaline region. The fluid was set to mix for 20 minutes and then set aside to cool before conducting any experiments.

The experimental analysis was initially performed on the base fluid to understand the nature of fluid loss of the prepared fluid without the addition of fluid loss reducers or nanoparticles. The laboratory measurements included measuring mud weight, pH, viscosity, and standard API filter test.

Nanoparticles Size and Composition Verifications

The next step was to test the drilling fluid with addition of nanoparticles. The nanomaterial used in this work was silicon oxide (SiO_2). Three different sizes of nanoparticles (sizes 1, 2, and 3) were tested and compared to find the best nanoparticles size range in terms of fluid loss reduction. The size range of nanoparticles used is shown in **Table 1**.

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[4] Sensoy, T., Chenevert, M. E., and Sharma, M. M. 2009 .Minimizing Water Invasion in Shales Using Nanoparticles, SPE 124429, presented at SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana.

[5] Nabhani, N. and Emami, M. 2012 .The Potential Impact of Nanomaterials in Oil Drilling Industry, Nano con 201, 23- 25, 10, 2012, Brno, Czech Republic, EU.

[6] Abdo, J. and Haneef, M. D. 2010 .Nanoparticles: Promising Solution to Overcome Stern Drilling Problems, NSTI-Nanotech 2010, www.nsti.org, ISBN 978-1-4398-3415-2 Vol. 3.

Table 1: Size range and surface area of nanoparticles used			
Type	Size 1	Size 2	Size 3
Size Range	5-15 nm	10-25 nm	70-95 nm
Surface Area	200 ± 25 m^2/g	120 ± 20 m^2/g	60 ± 10 m^2/g

SEM Data

The three different size ranges of nano-silica were examined under the Scanning Electron Microscope (SEM) at Yousef Jameel Research Center at the American University in Cairo to make sure that they are within the specified range. The next Figures show the Yousef Jameel-SEM at American University in Cairo and its results for each size (Figures 1 to 6).

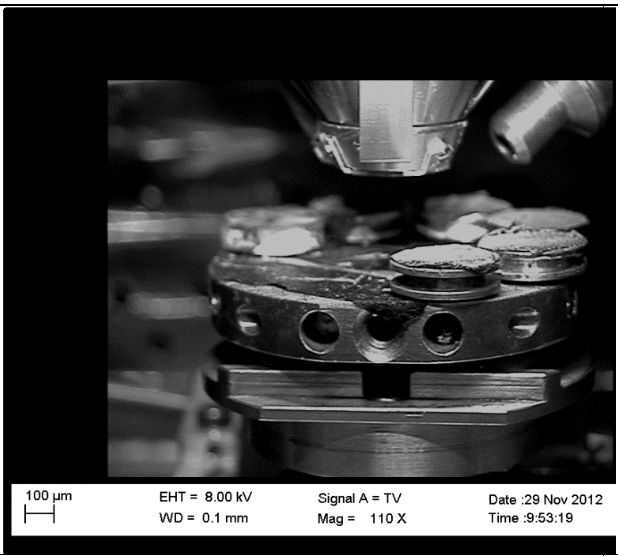


Figure 1: SEM interior lens

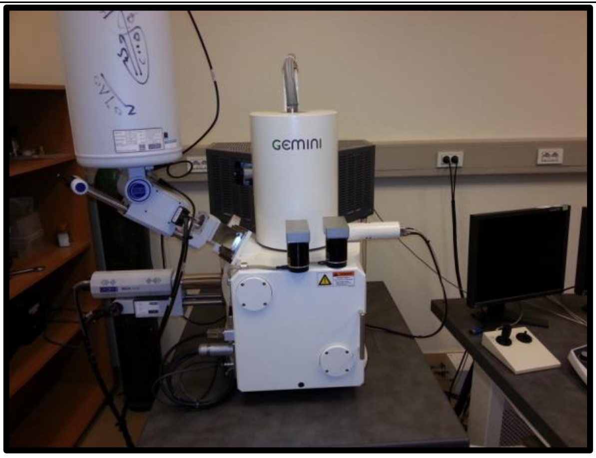


Figure 2: SEM apparatus

Figure 3: SEM monitoring screen

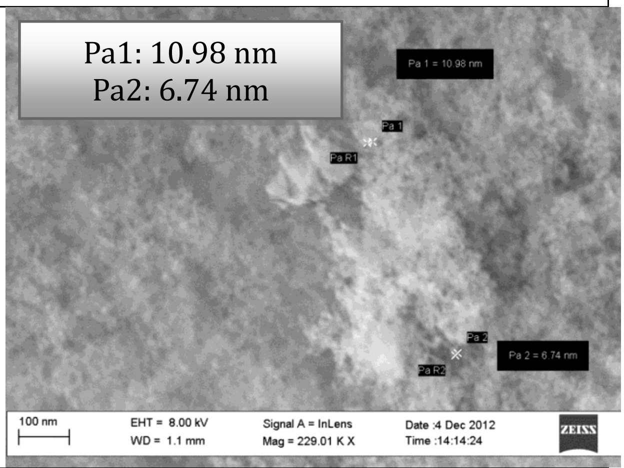


Figure 4: SEM image for size 1

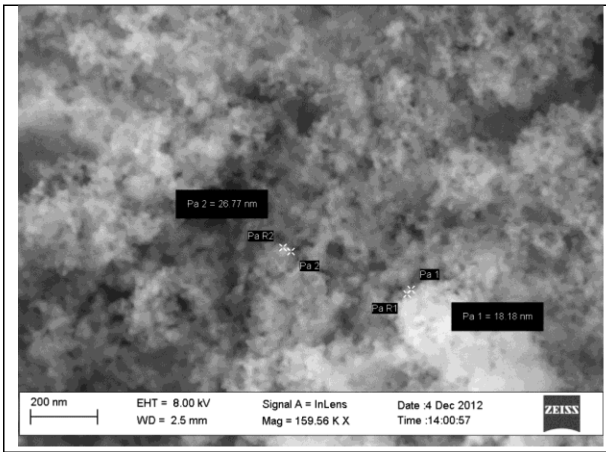


Figure 5: SEM image for size 2

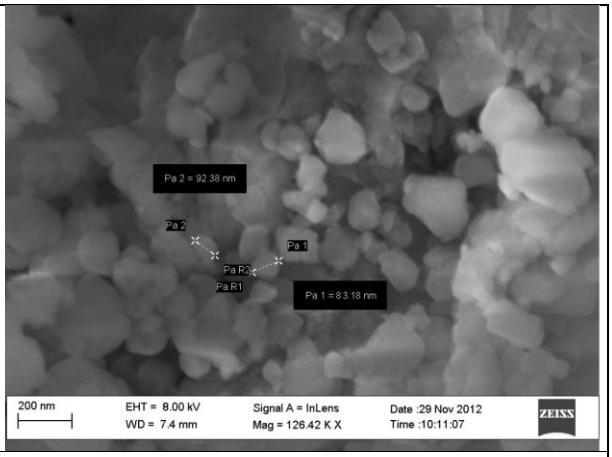
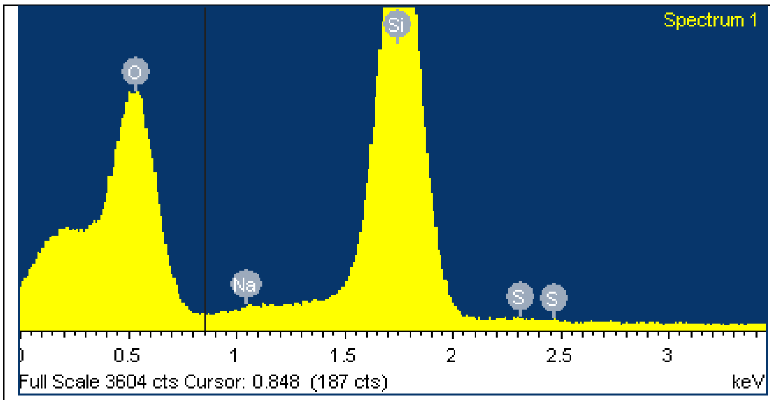


Figure 6: SEM image for size 3

Nano-silica Compositions by EDX

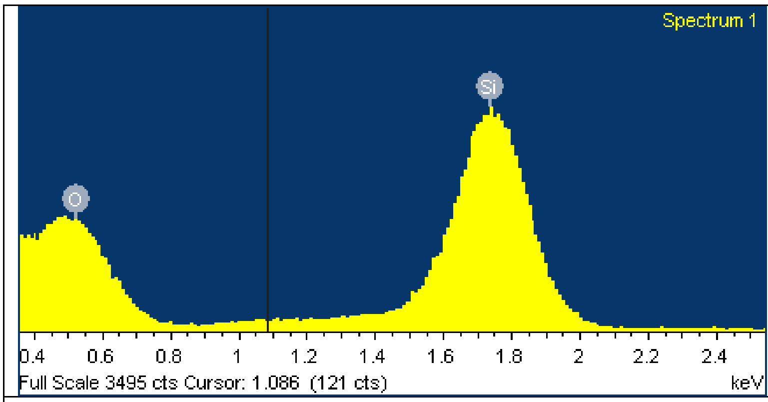
The used nanomaterials were bought from China, and so there is a need to verify the composition as well. In order to verify the composition of the nanoparticles used, EDX (Energy Dispersive X-ray) spectroscopy was used. EDX relies on the investigation of the excitation of the sample when struck by a beam of electrons. This excitation is observed by X-ray emission from the sample, which is measured by an X-ray spectrometer. Depending on the proton number of the atoms of the samples, different peaks appear in the results; each peak representing a certain element. The higher the peak, the higher the percentage composition of this element is in the specimen. An example of EDX results is shown in Figure 7a, 7b, and 7c for each size.

According to the EDX results for the 3 sizes, they all have major composition of silicon (Si peak) and Oxygen (O-peak). In the case of size 1, there were traces of sodium (Na-peak) and iron hyposulfite (S-peak). These traces however will not have a considerate effect on the experiment and shall therefore be ignored.



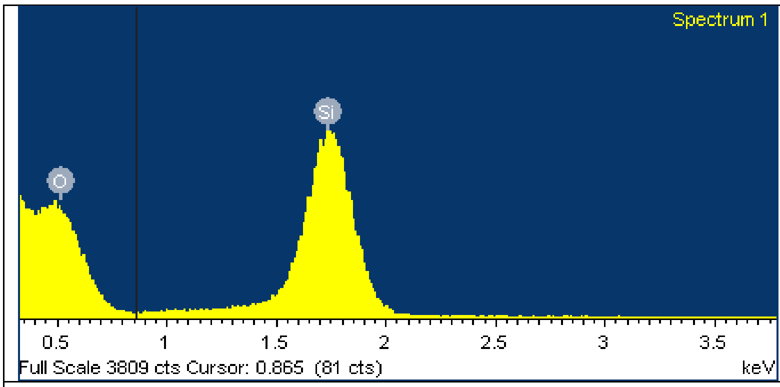
Element	Weight %	Atomic %
O	50.62	64.19
Na	1.13	1.00
Si	47.86	34.57
S	0.39	0.25
Total	100.00	

Figure 7a: EDX results for Nanoparticle material size 1.



Element	Weight%	Atomic%
O	51.17	64.78
Si	48.83	35.22
Total	100.00	

Figure 7b: EDX results for Nanoparticle material size 2.



Element	**Weight %**	**Atomic %**
O	52.22	65.74
Si	47.78	34.26
Total	100.00	

Figure 7c: EDX results for Nanoparticle material size 3.

Results and Discussions

Two groups of experimental runs where performed, and the results of each are presented and analyzed. The first set of runs included five different mud formulations. The criteria are to compare between the conventional and nanomaterial muds. The nano-material used is from silica, and the sizes were three different sizes, 5-15 nm, 10-25 nm, and 70-95 nm. The second set is using the optimum size defined from the first set at different concentration and changing its concentration in order to define the optimum concentration. By the end of both groups, the size and the concentration was determined.

The first set of runs was performed to compare the nano drilling fluids and the conventional muds in order to minimize the formation damage and fluid loss. A control base run must be performed for any experimental procedure in order to compare data one can get. In this case, the base run is the mud sample with no nanoparticles and no fluid loss additives (Mud #1). Another mud sample contained conventional fluid loss additives only (PAC-HV and PAC-LV) to compare the efficiency of nanoparticles with conventional fluid loss reducers (Mud #2). Next, we examined three different size ranges of nanoparticles in Muds #3, #4, and #5 to choose the best size range to continue our experiments with. Of course, these muds were prepared with the same concentration which is 10 %.

For ease of identification in the first set of experiments, the various mud samples that we worked with were designated by different numbers. The sample nomenclature is as listed below.

Mud #1: Drilling fluid with no fluid loss reducer or nanoparticles
Mud #2: Drilling fluid with fluid loss reducer only
Mud #3: Drilling fluid with size 1 nanoparticles at 10% concentration

Mud #4: Drilling fluid with size 2 nanoparticles at 10% concentration
Mud #5: Drilling fluid with size 3 nanoparticles at 10% concentration

Mud #1 (Base run)
The first step was to prepare the base fluid, which is a 9 PPG drilling fluid with no fluid loss reducer or nanoparticles. Table 2 lists the different mud additives used in the formulation of the base water-based mud along with the recommended concentrations of each additive.

Table 2: Additive used in Mud #1

Component	Quantity	Weight percent
Water	336	89.505
Caustic Soda (NaOH)	0.25	0.066
Soda Ash (Na_2CO_3)	0.25	0.0666
Potassium Chloride (KCl)	10.4	2.770
Xanthan Gum	1.50	0.3996
Barite	27.0	7.192
Total Weight	375.4	100

Test Results of Mud #1 (Base run rheology)
Before discussing the results of the first run which it is the control run, the rheology was measured and listed below:

1. **Mud density:** The measured value of mud density is **8.9 ppg**
2. **pH:** The measured value of pH is **10.1**
3. **Viscosity:** the plastic viscosity and yield point are measured and their values are 5 cp and 14 lb/100 ft^2.
4. **Standard API filter test:** while performing the API filter test, the data are measured regularly and recorded. The total collected filtrate volume is 12.2 mL. The filter loss volume is plotted versus the time as shown in Figure 8.

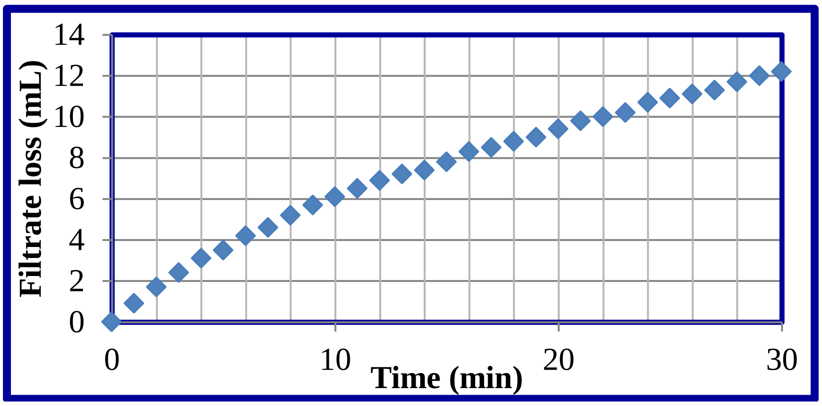


Figure 8: API filter test results for Mud #1

Mud #2 (Conventional fluid loss reducer)

The difference between Mud #1 and Mud #2 is that Mud #2 has conventional fluid loss reducers (PAC-LV and PAC-HV) added to it. The reason behind using conventional fluid loss reducers is to have filtrate loss data for conventional fluid loss additives already being used in the field to compare the effect of nanoparticles with later on. Therefore, we can decide whether using nanoparticles has better effect in reducing fluid loss than using conventional fluid loss reducers and if so we carry on with choosing the best size and concentration of nanoparticles through an optimization process. Table 3 shows the concentration of additives used in preparing Mud #2.

Table 3: Mud #2 Formulation

Component	Quantity	Weight percent
Water	336	88.736
Caustic Soda (NaOH)	0.25	0.066
Soda Ash (Na2CO3)	0.25	0.066
Potassium Chloride (KCl)	10.4	2.747
PAC-LV	3	0.792
PAC-HV	0.25	0.066
Xanthan Gum	1.5	0.396
Barite	27	7.131
Total Weight	378.65	100

Test Results of Mud #2

1. **Mud density:** The measured value of mud density is **9 PPG**
2. **pH:** The measured value of pH is **10.1**
3. **Viscosity:** the measured plastic viscosity and yield point had the values of 15 cp and 19 lb/100 ft^2 respectively
4. **Standard API filter test:** while performing the API filter test, the data were measured regularly and recorded. The total collected filtrate volume was 10.1ml. The filter loss volume is plotted versus the time as shown in Figure 9.

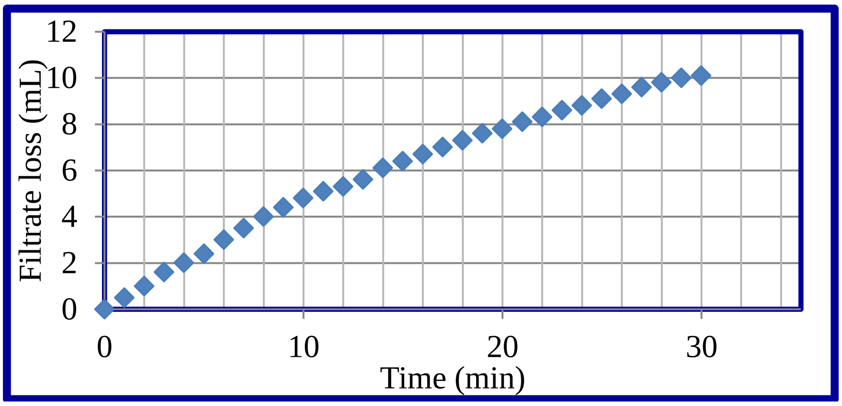


Figure 9: API filter test results for Sample 2

Effect on Nanomaterial Size: Nano-fluid Muds:

In order to check the effect of nanomaterial size, we prepared three different samples using three different nanomaterial sizes. These are size 1 (10-5 nm), size 2 (10-25 nm), and size 3 (75-90 nm). The concentration used for these samples is 10 gm per 100 ml solution (10 wt/vol.%. The samples of drilling fluid containing the nanoparticles were then prepared using 1.5% by volume colloidal suspension, which is equivalent to 5 ml. The following three Muds (3, 4, and 5) contain 0.5 grams of nanoparticles of different size ranges suspended in 5 ml of solution. The weight percentage distribution for the components of the three samples is basically the same as shown in Table 4.

Table 4: Muds #3, #4, and #5 concentrations

Component	Quantity	Weight percent
Water	334.2	89.3344
Caustic Soda (NaOH)	0.25	0.066827
Soda Ash (Na2CO3)	0.25	0.066827
Potassium Chloride (KCl)	10.4	2.780005
Xanthan Gum	1.5	0.400962
Barite	27	7.217322
Size 1 Nanoparticles	0.5	0.133654
Total Weight (g)	374.1	100

Test Results of Muds #3, #4, and #5 (10% Nano)

a) **Mud density:** The measured value of mud densities are **9, 9, 9.1 ppg for samples 3, 4, and 5 respectively**

b) **pH:** The measured values of pH are **10, 10.1, 10 for samples 3, 4., and 5 respectively**

c) **Standard API filter test:** The total collected filtrate volumes are 7**.15 mL for sample 3, 7.5 mL for sample 4, and 9.7 mL for the last sample number 5**.

The data for samples 3, 4, and 5 are plotted together in one graph as shown in Figure 10, followed by the column graph showing the final results for each size as depicted in Figure 11.

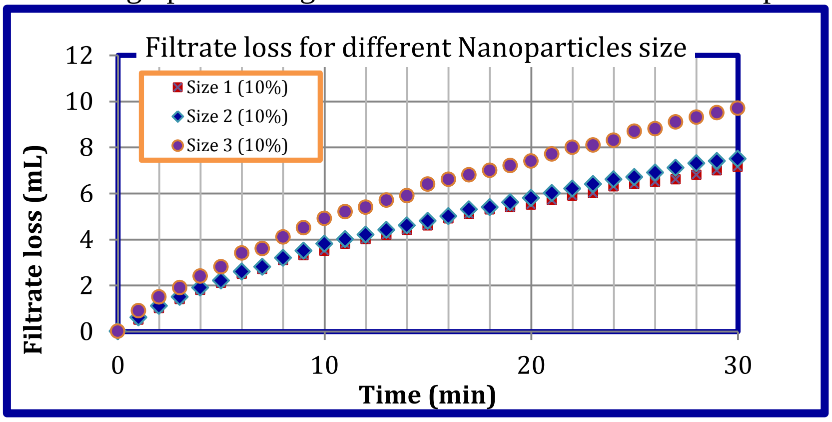


Figure 10: Comparison between Muds #3, #4, and #5.

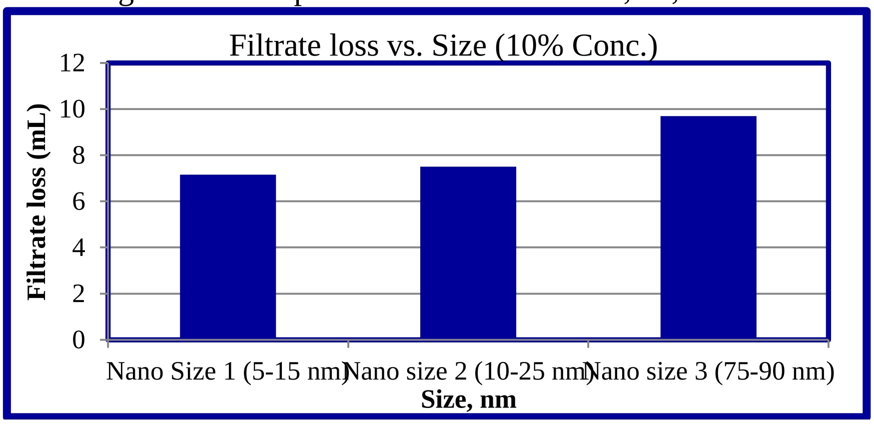


Figure 11: Graphical representation of filtrate volumes for the 3 different sizes

Optimum Nanoparticle Size

Based on the previous results for the last three nano-sizes used, in general, the API fluid loss of the three samples saw a significant decrease in fluid loss over a period of 30 minutes. Figures 12 and 13 shows the effect of the nanomaterials (10 % concentration) on the final filtrate loss, it is very clear that as the nanomaterial size decreases as the filtrate loss decreases, and hence the best or the optimum size is the last size which is 5-15 nm. This result is attributed to the fact says that, if the smallest materials enter between the coarser grains in the mud cake, they block it for further penetration, so the small size is blocking the pores for any further movements.

By combining all these results of the five runs till now, and plotting them in on a single graph as shown in Figure 12, one can conclude that, the nano fluid is better than the non-nano fluids, and among the nano fluids, as the nano size decreases as the fluid filtrate decreases which gives a reason to use only smaller nano –sized drilling fluid

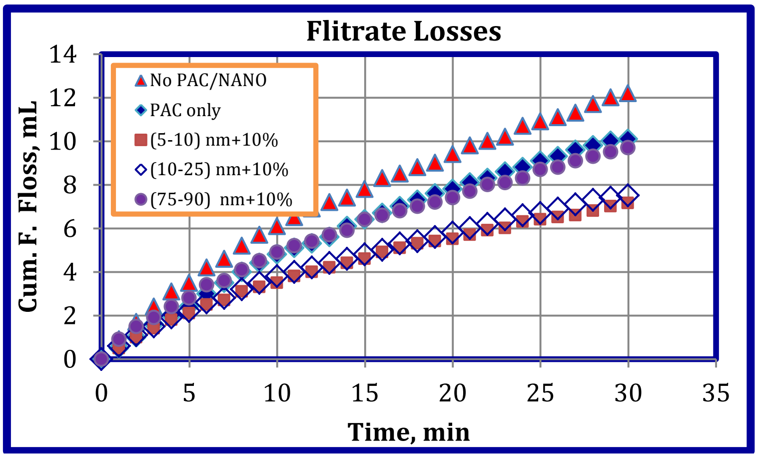


Figure 12: comparison between nano fluid and conventional ones.

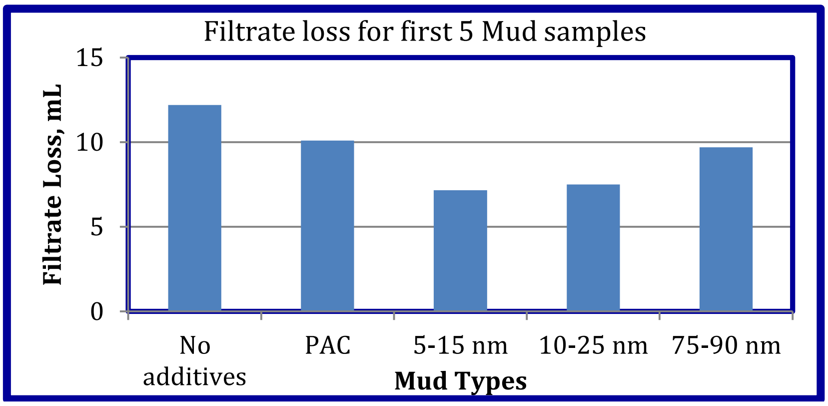


Figure 13: Graphical representation of filtrate volumes for all 5 samples

The final filtrate fluid loss of each run is tabulated in Table 5. Before the addition of nanoparticles, the filtrate volume was 12.2 mL, which was greatly reduced with addition of nanoparticles. The addition of conventional fluid loss additive in sample 2 did not have much impact although it decreased the fluid loss in comparison with sample 1, which is the base fluid sample, yet it had less impact than nanoparticles as shown in **Table 5 and Figure 13** where the effectiveness of the Nanoparticles as a fluid loss additive can be clearly seen. It has better reduction in fluid loss than the standard fluid loss additive used in this experiment. Sample 3, which utilized size 1 (5-15 nm), had the best performance of the three samples with the least fluid loss volume at 7.15 mL. By comparing the filtrate volume of sample 3 with the filtrate volume of the base fluid in sample 1, one can conclude that a reduction of 41.39% in fluid loss could be achieved by the addition of nanoparticles to the drilling fluid as shown in Figure 14.

Table 5: Filtrate loss for all five different muds

Sample No.	Loss, mL	Reduction to Base	% Reduction
1	12.2	0	0.00
2	10.1	2.1	17.21
3	7.15	5.05	41.39
4	7.5	4.7	38.52
5	9.7	2.5	20.49

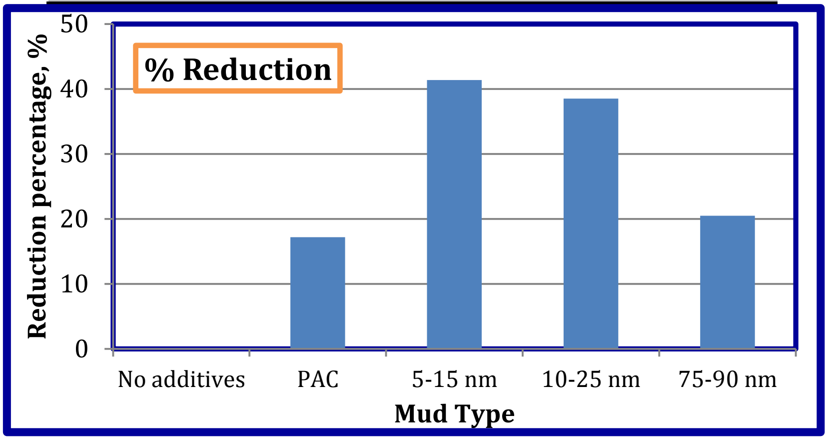


Figure 14: Reduction percentages for the different mud sample used

Investigate the Nanomaterial Concentrations

After investigating and selecting the best size range of nanoparticles among the three sizes in the last section (size 1: 5-15 nm), it is preferred to use that size and changing the concentrations in order to study the effect of concentration variations, i.e. continue the experiments further on with the same size range to find the optimum concentration to be used. Therefore, the concentration will be changed with an increment of 10% to find the optimum nanoparticles concentration range that will yield the least filter loss taking the cost in consideration as depicted in Figure 15.

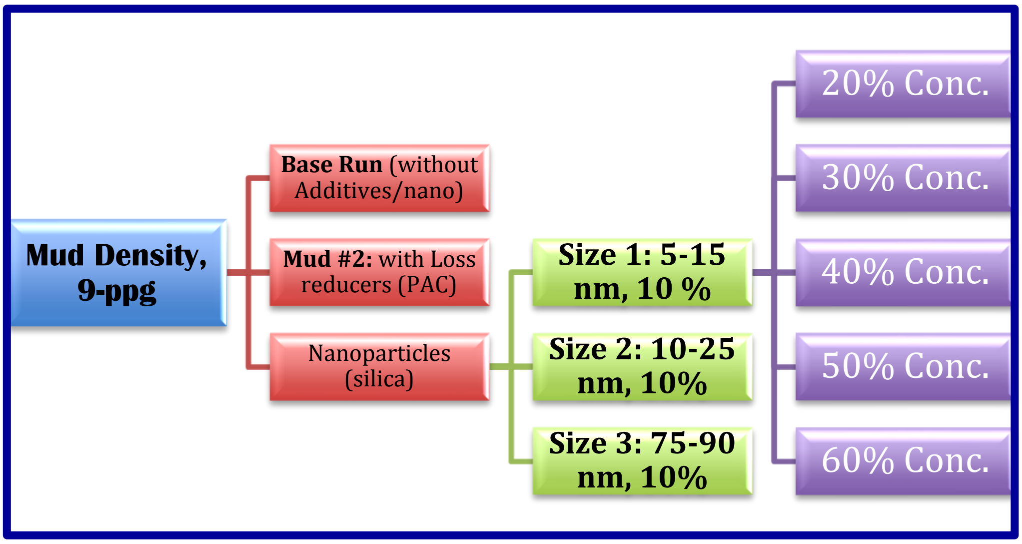


Figure 15: Chart showing the different concentrations used in the experiment

For ease of identification, the various mud samples that we worked with were designated by different numbers. The sample nomenclature is as listed below.

Mud #3: Drilling fluid with size 1 nanoparticles at 10% concentration
Mud #6: Drilling fluid with size 1 nanoparticles at 20% concentration
Mud #7: Drilling fluid with size 1 nanoparticles at 30% concentration
Mud #8: Drilling fluid with size 1 nanoparticles at 40% concentration
Mud #9: Drilling fluid with size 1 nanoparticles at 50% concentration
Mud #10: Drilling fluid with size 1 nanoparticles at 60% concentration

Table 6 shows the concentration of additives used in preparing Muds #3, #6, #7, #8, #9, and #10. The difference is in the weight of nanoparticles added to the samples.

Table 6: Concentrations of additives used in the preparation of Muds 3, 6, 7, 8, 9, and10.

	Mud #3		**Mud #6**		**Mud #7**		**Mud #8**		**Mud #9**		**Mud #10**	
Component	wt,g	Wt%	wt,g	Wt%	wt,g	Wt%	wt,g	Wt%	wt,g	Wt%	wt,g	Wt%
Water	334.2	89.33	334.2	89.22	334.2	89.10	334.2	88.98	334.2	88.86	334.2	88.74
Caustic Soda (NaOH)	0.25	0.07	0.25	0.07	0.25	0.07	0.25	0.07	0.25	0.07	0.25	0.07
Soda Ash (Na2CO3)	0.25	0.07	0.25	0.07	0.25	0.07	0.25	0.07	0.25	0.07	0.25	0.07
Potassium Chloride (KCl)	10.4	2.78	10.4	2.78	10.4	2.77	10.4	2.77	10.4	2.77	10.4	2.76
Xanthan Gum	1.5	0.40	1.5	0.40	1.5	0.40	1.5	0.40	1.5	0.40	1.5	0.40
Barite	27	7.22	27	7.21	27	7.20	27	7.19	27	7.18	27	7.17
Nano Size no.	0.5	**0.13**	1	**0.27**	1.5	**0.40**	2	**0.53**	2.5	**0.66**	3	**0.80**
Total Weight (g)	374.	100	374.	100	375.	100	375.	100	376.	100	376.	100

While performing these five experiments (Mud samples 6, 7, 8, 9, and 10), the mud density is approximately constant at 9 ppg level as well as the pH value at a level of 10. The API filter loss results for each experiment is listed and monitored. The filter loss volume for each run after 30-min/100 psi is tabulated in the following table (Table 7) for sake of comparison, and presented in Figure 16.

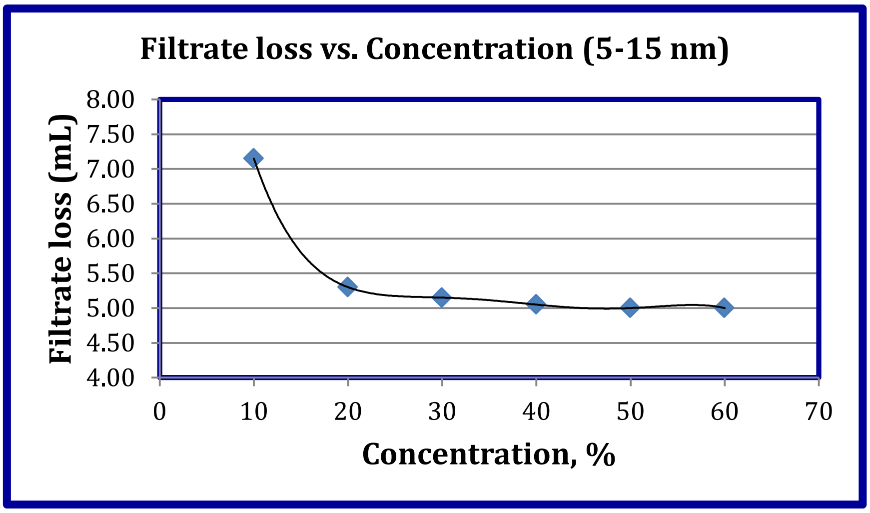


Figure 16: Graphical representation for filtrate loss results of different concentrations

Selected Optimum Nanoparticle Concentration

Increasing the concentration of the Nanoparticles has a considerable effect in reducing the fluid loss of the drilling fluid. The readings from Table 7 show the effects of increasing nanoparticle concentration on the collected volume of filtrate. 10% wt./vol. reading has a fluid loss of about 7.15 mL, and increasing the concentration to 20% has reduced the fluid loss by 25.87%. Thus the concentration of nanoparticles is a very important parameter in fluid loss reduction along with the size of nanoparticles.

Table 7: Filtrate volumes for the 6 different Concentrations

Concentration	Filtrate volume (mL)	Reduction Volume, mL	Loss Reduction, %
10%	7.15	0.00	0.00
20%	5.3	1.85	25.87
30%	5.15	2.00	27.97
40%	5.05	2.10	29.37
50%	5	2.15	30.07
60%	5	2.15	30.07

As the concentration increases the fluid loss decreases; however, the most fluid loss reduction is observed when increasing the concentration from 10% to 20% as illustrated in Table 7. Further increase in concentration of nanoparticles doesn't economically serve its objective because the cost surpasses the benefits at concentrations above 20%. As depicted in Table 7, with 10 % increase in concentration, a 1 % filtrate loss reduction is achieved. Therefore, the most economic and yet effective concentration of nanoparticles is the range between 20% and 30% wt./vol, i.e. starting from 20% and ends with 30%, any further increasing in concentration will not provide the objective loss reduction. By comparison this result with filter loss of conventional mud result, it is found that it leads to a 56.56% reduction in fluid loss in comparison with the base fluid. Figure 17 displays the filtrate loss volumes for the base fluid, fluid with conventional fluid loss reducer, and the fluid with optimum nanoparticles concentration within the 20%-30% range.

The rheology properties of the optimum nano or smart drilling fluid are listed in in Table 8.

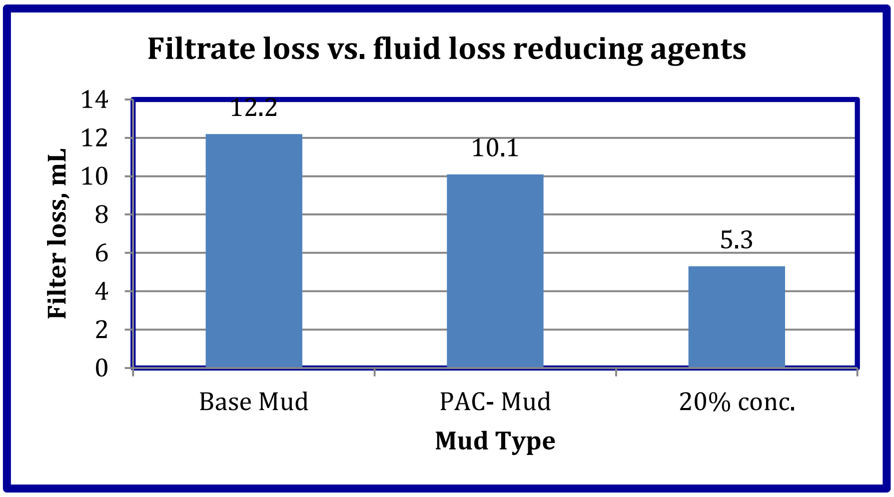


Figure 17: Filtrate loss for different fluid loss reducing agents

Table 8: Nanoparticle rheology

Optimum Nanoparticle Conc. Rheology	
600/300	**26/22**
Plastic Viscosity (@600 - @300)	**4cP**
Yield Point (@300 – PV)	**18lb/100 ft.**

Conclusions

Several conclusions have been drawn from this work, some of them are:

1. The properties of drilling fluid is very critical for reducing formation damage while drilling operation
2. The fluid loss reduces have a greatly effect on filtrate fluid loss in the formation, and hence reduces the damage and provide a smooth drilling operation.
3. In the age of nano technology, the conventional filtrate loss agents are becoming not suitable for the drilling nowadays.
4. The nanoparticles proved to be more effective in reducing the filtrate losses than conventional fluid loss reducer (PAC-LV and PAC-HV).
5. The smaller nano sized drilling fluids proved to have a greater effect of the filtrate loss volume in to the formation and subsequently less drilling damage.
6. The optimum size for drilling fluid formulation is ranged from 5-15 nm silica nanoparticles.
7. The optimum concentration range was found to be within 20% - 30% concentration range reducing filtrate loss by 47.52%- 49.01% respectively compared to conventional fluid loss reducers (PAC).