ENHANCEMENT OF FILTRATE LOSS CONTROL USING SMART NANO-WBM TO MINIMIZA TIGHT SPOTS PROBLEMS IN WELLBORE

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Dissertation submitted in partial fulfillment of the requirements for the Degree of Study (Hons) (Petroleum)

May 2015

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Approval Certificate

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Originality Certification

I, Ahmed Mohamed Naguib Fahmy Khatab Hereby, that this document is from my own work , including all the sections but the parts specified in the references and the acknowledgements and there is no work done in this paper by unmentioned source or person .

Ahmed Khatab

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Thanks to AL-MIGHTY ALLAH for giving me the strength and the guidance, without his might, nothing can be done

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Thanks to my Mother, with her continuous support to me during my whole studies, I would not become the man I am without her.

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Abstract

The objective of this project is to use a smart nano drilling fluid which is prepared using nano size bentonite clay which has an enhancement of its rheological properties of the mud especially quick plastering of the wall of the wellbore based on the efficient filtrate loss control into the high porous and high permeable formation.

The appreciable enhancement in the filtrate loss control properties is expected by using thus smart nano drilling fluid as compared to the conventional water based mud

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Chapter 1
Introduction

1.1 Background Study

The demand for energy in the world is increasing hand in hand with the demand for oil. The easy oil is gone and the wells drilled now are increasingly more difficult. One of the most important factors for drilling advanced wells is the drilling fluid. Nanotechnology in drilling fluid may prove to be a new generation of drilling fluid. In drilling fluid the nanoparticles can reduce friction and wear and improve the rheology of the fluid.

Nano-technology could be used to enhance the mud cake, stabilize shale, protect against corrosion and enhance cement. The cost of lost drilling fluid can be significant; also loosing mud into the formation can decrease the production capability of the well due to increased skin factor.

This study has tried to improve filtration properties of the drilling fluid with adding nanoparticles to it. The nanoparticles are supposed to go in between the larger particles and block the flow through them. The study has also looked at how the rheology profile changes with the addition of the particles.

During the drilling operation, there is a flow encountered through porous formation due to the permeability of these formations. However, this flow depends mainly on the relationship between the hydrostatic pressure of the drilling fluid column and the pressure of the fluids in the porous formation around the wellbore.

Since the flow of the fluids is always starting from the high pressure point to the low pressure point, Drilling engineer's task is to always keep the hydrostatic pressure higher than the pressure of the formation around the wellbore, consequently there will be no flow coming from the formation and entering the wellbore which may cause a kick then a blowout if left without solving it.

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While drilling engineers make sure there is no flow from the fluid formation to the drilling fluids in the wellbore, doing the opposite is almost near to impossible especially in the high permeable formation which makes the phenomena of the drilling fluids breaking through the formation porous media is unavoidable while drilling.

While the drilling fluids tend to penetrate the permeable formation around the wellbore, layers of filter cake of drilling fluids and solids will be deposited on the wall of the wellbore, the more the filtrate cake will result in thicker layers which might seems harmful at the beginning but if it is looked thoroughly, a lot of problems will come to the surface such as tight spots of the wellbore, increased torque and drag, poor log quality, stuck pipe, loss of circulation and formation damage (Simpson el al., 1974).

From the last points, the urge of creating a way to prevent an excessive filtrate loss and to design a drilling fluid system to deposit a thin low-permeability filter cake on the formation to limit the invasion of drilling fluid filtrate into the formation has become inevitable necessity in the oil and gas field

There is no doubt that the usage of oil based drilling fluids in oil and gas industry has been increasing especially in the past several years due to being an effective invert-emulsion system beside its stability especially in troublesome drilling cases such as water sensitive’s shale

However the advantages the oil based drilling fluids has, but its disadvantages can`t be overlooked such as the high cost required to prepare an oil based mud and it is drastic consequences on the environment where it is used.

Nanotechnology is the manipulation of matter on an atomic molecular and supramolecular scale. The earliest, widespread description of nanotechnology referred to the particular technological goal of precisely manipulating atoms and molecules for fabrication of macro scale products(Serrano E, 2009).

This research paper investigates the usage of smart nano drilling fluid which is prepared using nano-size bentonite clay by enhancing its rheological properties especially quick plastering of the wall of the wellbore based on efficient filtrate loss control into the highly porous and permeable formations.

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Currently only a handful papers have studied the effect that nanoparticles have on the filter cake. The common practice in the industry is to add macro materials or LCMs like bentonite, barite, calcium carbonate or graphite to build a decent filter cake. When allowed by the government, it is also possible to use an oil based mud which gives little fluid loss.

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1.2 Problem Statement

Hydrostatic pressure of drilling fluids plays an important role in drilling operations since the hydrostatic pressure of these fluids must be more than the pressure of the fluid in the formation around it to prevent a kick to happen. And it is also responsible of flowing the drilling fluid to the formation around the wellbore especially in high permeability, high porosity formations.

While encountering a high porous and high permeable formation during drilling, an excessive amount of filtrate loss into this porous media can be detected which will result in a thicker layer of mud cake around the well bore , this thick layer may cause a lot of troubles like tight spots and loss of circulation.

This research is concerned about the high filtrate loss into the porous and the permeable formation which result in a thicker mud cake at the wellbore wall which may lead to well bore problems.

Objectives and scope of study

The objective of this project is to use a smart nano drilling fluid which is prepared using nano size bentonite clay which has an enhancement of its rheological properties of the mud especially quick plastering of the wall of the wellbore based on the efficient filtrate loss control into the high porous and high permeable formation.

The appreciable enhancement in the filtrate loss control properties is expected by using thus smart nano drilling fluid as compared to the conventional water based mud

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Chapter 2

2. Literature review

2.1 Drilling fluids

The term “Drilling fluid” is used for the fluid which is inserted and circulated while drilling or tripping in order to provide balance between the formation fluid and the borehole beside some other functions to get the drilling job successfully done with the lowest problems encountered.

Drilling fluids, commonly referred to as the drilling muds, are a vital part and the life blood of a successful drilling operation, The cost of the fluid system often represents one of the single peak capital expenditure in drilling a new well. Fluid costs can shoot up swiftly when drilling deep holes, complex formations or in remote location to minimize the cost of drilling fluids and ensure an efficient drilling program fluid properties must be maintained incessantly during drilling operations.

Functions of Drilling Fluids:

1- Remove the drilling cuttings
2- Stabilizes the pressure resulted in the formation fluids.
3- Hole stabilization
4- Work as a cooler and lubricant to the drill bit and drill string.
5- Suspension of desired solids and ease of removal of undesired solids
6- Cleaning the drill bit

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The main idea of using drilling fluid is to offer a well stability to our drilling process and prevent problems. Thus it`s job does not only conclude on one task but doing several jobs at the same time and in different places in the drilling system for instance, in the annulus it is mainly responsible to carry the cutting , on the other side when drilling mud are around the in the bit region , its task becomes cleaning the hole as well as cooling the drill bit . it only takes one bad parameter to make one of these tasks fail and then lead to devastating consequences.

Devastating consequences caused by not obtaining the optimum rheology of the drilling mud are several and various depending on which section got affected by this parameter, some of these consequences are

1- Tight spots in the wellbore
2- Differential and mechanical Pipe sticking
3- Excessive Filtration loss that can cause loss in the circulation
4- Formation damage

All these consequences become much more readable when the drilling process is done under HPHT conditions since the drilling mud suffer from change of rheology in these conditions.

Out of these reasons, it became a necessity to find a way to degrade the HPHT effects on the drilling fluid to avoid these complicated problems while drilling. Recently adding several additives to the drilling fluid have been used to overcome this problem , Like polymeric and surfactant additives but that affect the integrity of our drilling mud causing a change in its characteristics

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Nano-technology drilling fluid prospective

The main idea of nanotechnology has caused our prospective scientific look to the problems we face in many fields of science to change due to the enhancements the nanotechnology has added to our science due to the capability to manipulate the structure of any fluid, material or product not only in its macro and micro scale but in nano scale as well which open for the same products the industries had before to have a new applications which were impossible before.

That does not stop in manufacturing industries only, but the oil and gas industry can have outstanding changes if the usage of nano technology have been put in its right place in the industry; decreasing the cost and the problems suffered using the normal size drilling fluid

Nano technology new capabilities has opened the options for the researches to think about changing and modifying the rheology of our drilling fluid and its composition in a way that serve our drilling process more efficiently regarding the cost and time which are the main two factors affecting our drilling process . that can be done by rearranging the molecules of the drilling fluids in nano-particles level so the sizes and densities and viscosities can change according to our needs.

As a brief of our possible benefits that we can obtain by using nano-technology in the oil and gas industry

From economic point of view:

1- Replacing the additives used to change the rheology of the drilling fluid by making nano-drilling fluid will save us the cost of purchasing these additives
2- Increasing our explorations and search for oil to places that were not economical before
3- Eliminate a big percentage of the wasted time due to well bore stability problems

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2.2 Hydrostatic pressure

The existence of the drilling fluid in the drilling string and the annulus creates a pressure known as the hydrostatic pressure, this pressure is dependent on two main variables which are the mud weight and the vertical depth and here are some equations to discuss the calculations of the hydrostatic pressure. Hydrostatic Pressure = 0.052 x weight of MUD (PPG) x True Vertical Depth (ft).

2.3 WELL BORE STABILITY

Stability of the wellbore is one of the most important task the drilling engineer perform cause unless the wellbore is stable, the drilled hole will not maintain its gauge size , shape or structural integrity.

While investigating the water sensitive shale formation, a lot of problems will pop up this is not solved up till now. There are two factors affecting the stability of the wellbore

1- the drilling fluid (Mud)
2- the rock mechanism

The key to stop the problems coming out from water sensitive shale is to minimize the interface contact between the water and the shale to avoid any undesired reactions which will cost us a lot of money to solve

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2.4 NANOTECHNOLOGY

Few years ago, nanotechnology were not recognized as a scientific option that can be used to apply new enhancements in the drilling process specially the most complicated engineered fluid which is the drilling fluid which has various applications in the drilling processed as discussed before.

However recently when nano-technology was introduced and up till now , all the scientific discoveries in nano technology has been able to modify and enhance our drilling fluid performance but it was mostly limited to research purposes since these researches have not reached a developed stage of solid continuous data that can be reliable to be used on the real life drilling processes due to lack of opportunities to take a risk of trying new methods which caused by the current economical problems in oil.

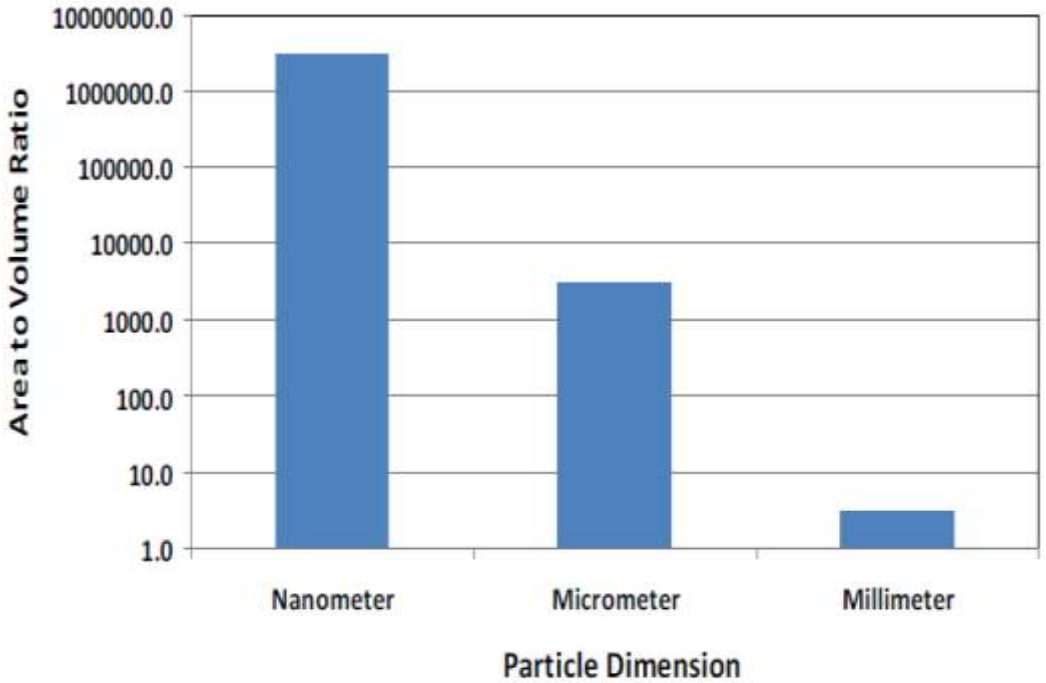

Figure 1 Area to volume ratio vs. spherical particles with diameter of 1nm, 1µm and 1mm [1]

Source:. R. Kelsall, I. Hamley, and M. Geoghegan.2005. "Nanoscale Science and Technology," John Wiley & Sons Ltd, 2005.

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Nano tech contribution

Various study has been done on nano-technology within oil and gas industry and some of these researches have shown a very promising results and in the section , some of these results will be displayed

The following figure measure the fluid loss Vs Pressure to Base fluid and base fluid with additives and nanoparticles base fluids, from the graph we can see that the nano=particles base fluid has a much lower fluid loss and it degraded the effect of increasing pressure on its rheology characteristics

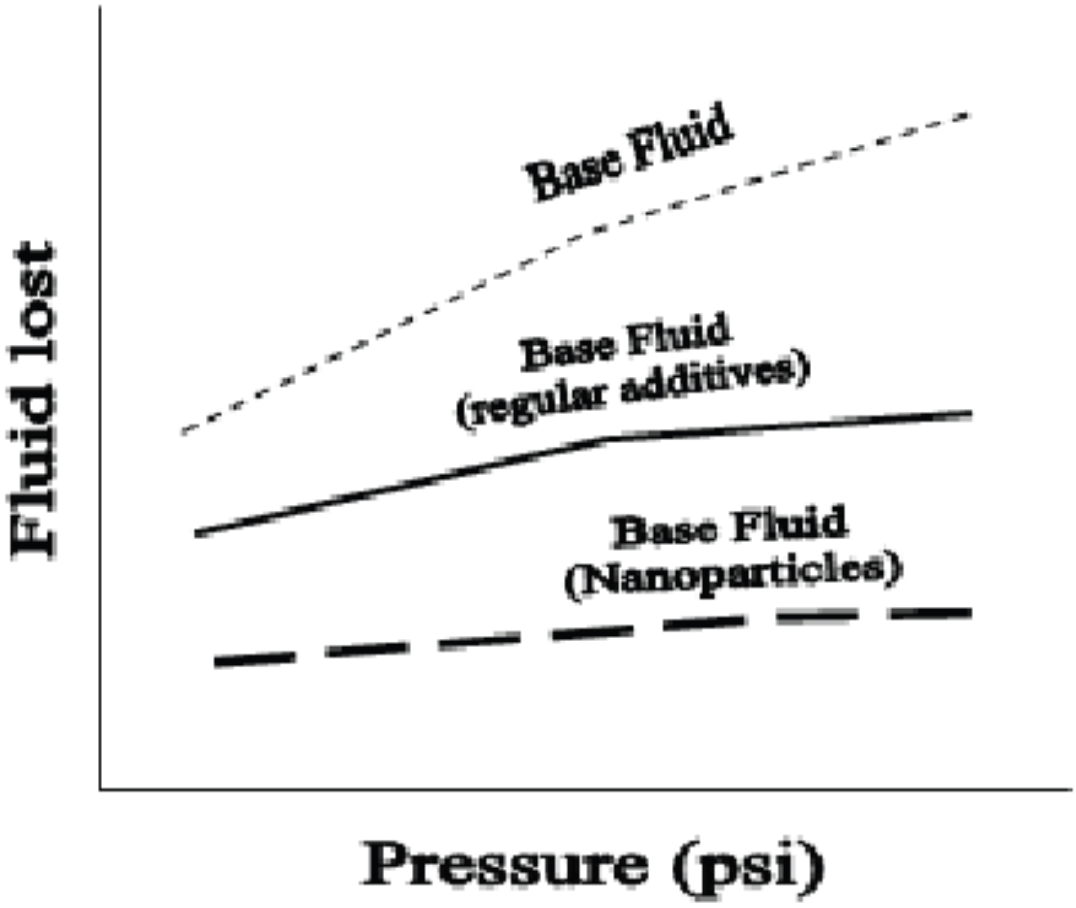

Figure 2 Expected fluid lost for Different types of fluids

Source: Md amanulah"Preliminary Test Results of Nano-based Drilling Fluids for Oil and Gas Field Application" SPE/IADC 139534. SPE Drilling

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Carbon Nano tubes

One of the outstanding discoveries in nano technology is the discovery of a new material called Carbon Nanotube (CNT), the main component is carbon but it is not as any other material as its shape in a nano level is like a tube , CNT diameter ranged from 0 to 100 nm it can't be seen with the naked eye unless it's in a big quantities agglomerated together

It has a non-broken hexagonal mesh rolling up a layer from graphite a long with the carbon molecules at the apexes of the hexagon. Some recent advancement of the field of nano technology has enables the scientists to make the nano tubes in lengths of many centimetres which enable to use its properties in the industrial applications.

CNTs can take on multiple shapes and lengths; it also can vary in its helicity type as long as number of layers, however it contains graphite but its properties are very different from the graphite especially in its electrical characteristics acting either as metal or semi-conductor.

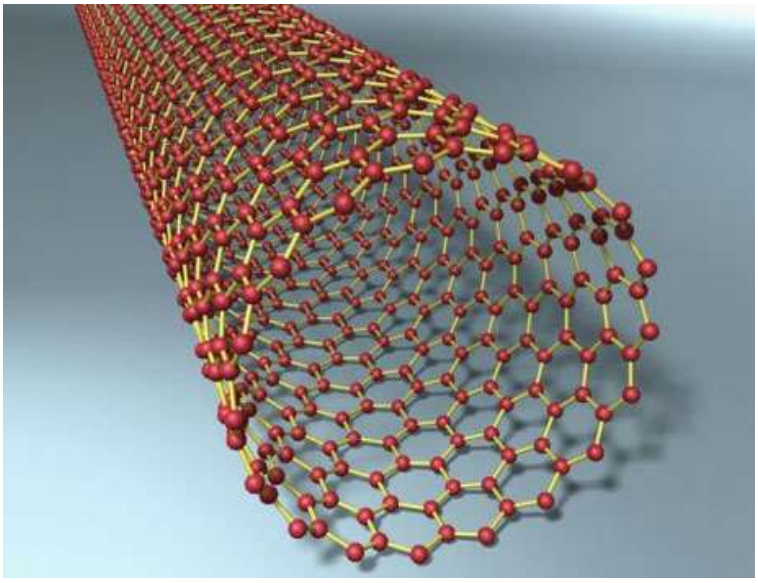

Figure 3 Arrangements for Carbon Nanotube Molecules

Source: Research paper: doi:10.1038/nature12502 – "Carbon nanotube computer"

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Chapter 3

Methodology

3.1 The Procedures

The following figure illustrates the phases of conducting the FYP. Further illustration will be included in 3.2 project activities

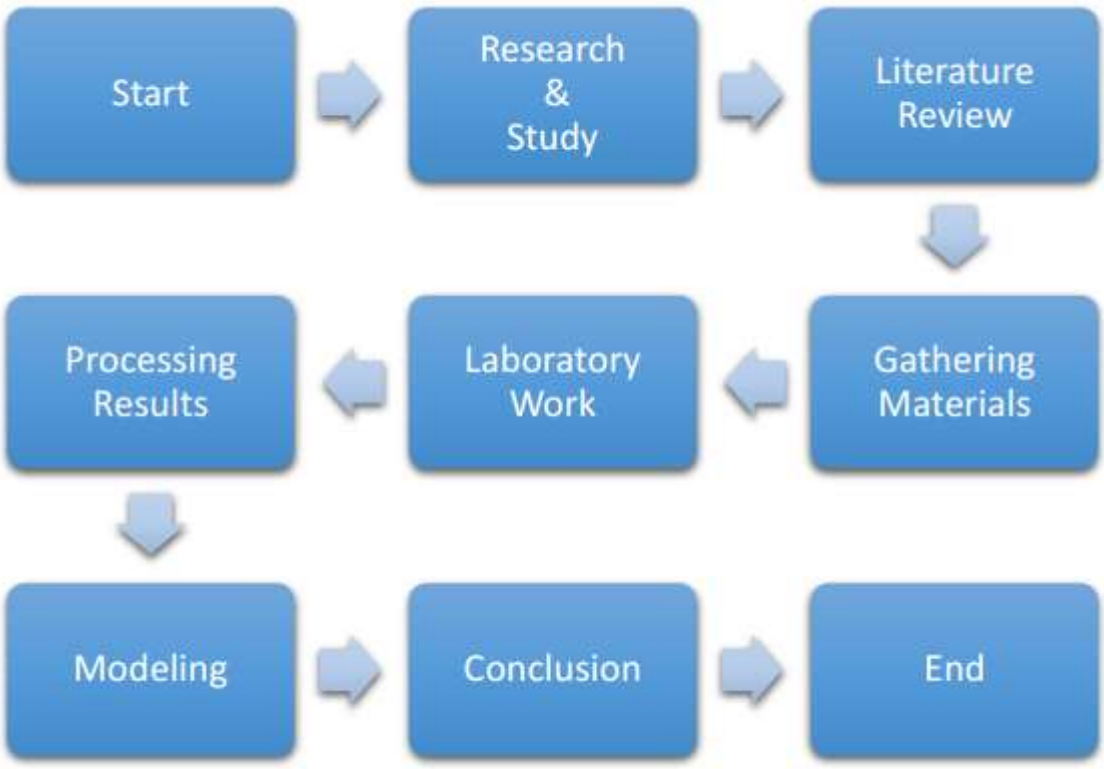

Figure 4 Research Methodology

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3.2project activity

1- Start: selecting the topic and meeting the supervisor.
2- Research and study: researching about the main keywords of the project and identifying the main problem and our main goals.
3- Literature review: writing the extended proposal of the project and including the problem statement and the timeline of conducting the project.
4- Gathering materials : reading a previous articles about the same topic or related topics plus identifying what kind of experiments needed to get the project done and locating where it can be found.
5- The laboratory work: conducting the experiments to identify the most feasible way to achieve our goal.
6- Processing results: analysis of the results which were collected from the laboratory experiments to identify the importance of this data.
7- Modeling: experimenting the final results on a simulation environment and creating a model of it in order to have more clear image of the project.
8- Conclusion: wrapping up the results of the project and identifying the percentage of success and failure of achieving our main goals
9- End

3.3Tools & equipments required

1- Nano and conventional commercial clay.
2- Filter press equipment.
3- Mud mixture.
4- Filter paper with different mesh size.
5- LPLT filter press equipment.
6- Ball milling machine
7- Multi mixer machine

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3.4 Experimental methodology

3.4.1 Preparing the Mud

After identifying the required mud weights which the experiment would be conduction with which are as follows:

1- Water based bentonite Mud 10 PPG.

2- Water based bentonite Mud 11 PPG.

3- Water based bentonite Mud 12 PPG.

For 10 PPG water Based bentonite Mud:

1- Prepare 22.6 g of bentonite plus 350 ml of water in Multi Mixer equipment

Figure 5 Multi Mixer Equipment

2- After 10 Minutes, the multi mixer machine is stopped.

3- For ease of calculation, density caliper is used to obtain the actual density

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Figure 6 Mud Balance Caliber

The actual density of the mud is 8.7 PPG

4- Following the formula for Barite

Barite = 1470*(w2-w1)/(35-w2)

5- From the previous equation we obtain that the required Barite mass to obtain 10 PPG of mud is 76.44 g
6- Adding the calculated amount of barite to the Mud using the multi mixer machine then calculating the density again to make sure of the estimated density, the calculated density and the density shown by the density caliper are identical.
7- Following the same procedures to obtain the 11 PPG mud and the 12 PPG mud resulted in the following composition of 11 and 12 PPG mud
8- 11 PPG mud contains 22.6 g bentonite+140.87 g barite + 350 ml water
9- 12 PPG mud contains 22.6 g bentonite+210.9 g barite + 350 ml water
10- Calculate the viscosity, yield point and Gel strength

Table 1 Drilling mud characteristics

parameters		10 PPG MUD	11 PPG MUD	12 PPG MUD
Rotor reading	θ600	28	33	38
	θ300	20	22	26
Viscosity C.P.		8	11	12
Yield point		12	11	14
Gel strength	10 seconds	13	15	16
	10 minutes	29	31	39

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3.4.2 Filter press experiment LPLT

Figure 7 LPLT equipment

Category	Specification
Working Pressure	100 psi (690 kPa)
Filtering Area	7.1 in^2 (45.8 cm^2)
Dimensions (Width x Depth x Height)	9 x 9 x 20 inches 22.86 x 22.86 x 50.8 centimeters
Weight	15 lb (6.8 kg)

Table 2 API Specification for LPLT equipment

1- Applying the assembly and the specifications shown above and putting the mud inside it
2- Then recording the filtration loss volume in respect with time (every 1 minute)
3- The next results are obtained from the 3 types of mud
4- Notice that the filtration loss is in ml

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Table 3 Fluid Loss Results with respect to time

Time (Minutes)	10PPG MUD	11PPG MUD	12PPG MUD
1	3	2	3.6
2	4.8	3.2	5.6
3	6.2	4.4	6.8
4	6.8	5.4	8
5	7.6	6.4	9
6	8.4	7.2	9.8
7	9.2	8	10.6
8	9.9	8.8	11.6
9	10.4	9.5	12.4
10	10.9	10.2	13
11	11.5	11.1	13.6
12	12.4	11.6	14
13	13.1	12.1	14.6
14	13.8	12.6	15.3
15	14.4	13.3	16
16	14.8	13.9	16.4
17	15.2	14.3	16.9
18	16	14.7	17.3
19	16.3	15.1	17.7
20	16.6	15.4	18

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3.4.3 Obtaining the nano sized particles by high energy ball milling

Ball milling is a mechanical process which is done by obtaining a powder for the solid needed to obtain smaller size from, then the bal miller is used to form a collider environment between the powder and the balls.

This experiment was performed in INC at 1960, the results of this experiment was promising since a nano size, well-dispersed particles were obtained from this mechanical process, the characteristics of the product from this experiment has very fine grains that is not easily manufactured by normal methodologies

The common way of conducting this experiment is by using planetary ball mill which causes mechanical alloying However the resultant from this experiment is in a very low quantity therefore it is not recommended to do it when there is a need of manufacturing in big quantities, though it is very useful in research purposes since it is cost effective

The structure of the ball mill is as followed:

1- A turn table
2- 2 or 4 bowls

Then an vice verse rotation technique is applied to obtain the optimum energy to be used to decrease the size of the particles to the desired size by the centrifugal forces, the mechanism of this process is more illustrated in the figure 8.

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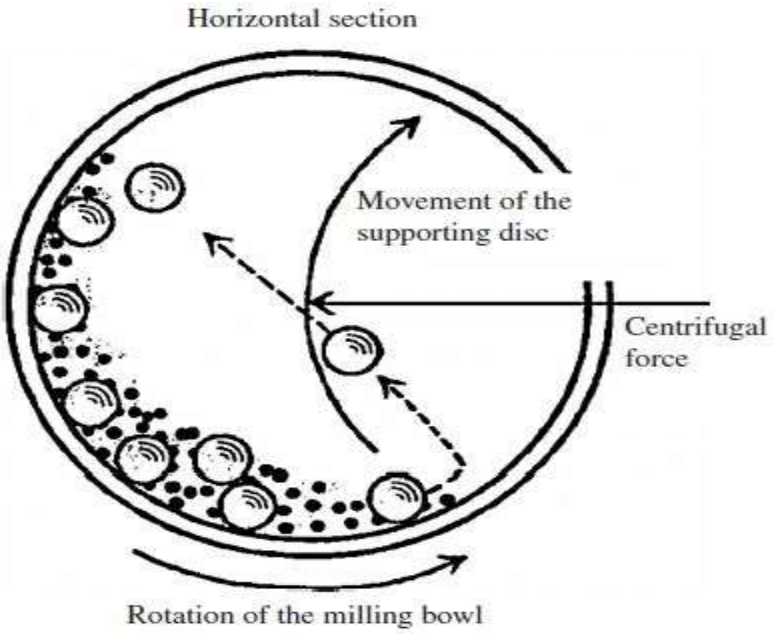

Figure 8 Schematic view of Balls and Powder Mixture

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3.5. Gantt Chart (TIMELINE OF THE PROJECT)

Table 1 show the Gantt chart and the progress of the project throughout the duration of FYP1.

details	weeks												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1-selecting topic													
2- researching the project													
3-preperation for extended proposal													
4-submission of extended proposal													
5-preparing for proposal defence													
6-proposal defence evaluation													
7-preperation of interim report													
8-submission of interim report													

details	weeks												
	1	2	3	4	5	6	7	8	9	10	11	12	13
9- preperation of the experiment													
10- conductiong the experiment													
11-collectioong more information													
12- preparing the progress report													
13-submission of the progress report													
14- preparing for presedx													
15-preparing for poster presentation													
16-preparing for viva													

Table 4 & 5 Timeline for experiment

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CHAPTER 4

4. CONCLUSION

While the oil based mud has been the most used as drilling fluid in the past few years to maintain the wellbore stability. However, the high cost of preparing this kind of mud has been a burden into the oil and gas companies and a main contributor to the high cost of the overall of the drilling job.

The usage of water based mud is very beneficial financially but it has a lot of problems especially when water sensitive shale is encountered while drilling since it has a bad effect on these kind of formation. From this point, the urge of investigating more , in order to contain these undesirable effects has increased and the eyes of the oil and gas companies have been overlooking every scientific solution to seek an answer.

The usage of the nano technology to manipulate the bentonite to increase its plastering effect around the wellbore is one of the possible solutions which should be investigated in order to reach out main goal which is achieving the wellbore stability and minimizing the cost at the same time.

Using nano-particles to enhance the filtration loss in the well bore has been proven effective since the filtration loss decreased up to 37%.

The nano particles have the tendency to accumulate on the wellbore side since it has the lowest size which result in the nano particles sealing the pores between the mud cake , in another word the well bore is being plastered by the nano-particles.

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Recommendation and Future work

The mechanism of the nano-particles plugging the pore spaces between the mud cakes to decrease the filtration loss has a lot of concerns and further investigations might be useful.

1. The rotation of the pipe might have a great effect on decreasing the filtration loss since it will push the nano particles away from it to the wellbore wall, which will result in a good plastering for the wall bore
2. Investigation on the effect of HPHT on the nano-particles might turn to be useful in order to understand the interaction that happen while drilling deep wells.

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