TITLE: Usage of Nanoparticles in Synthetic Based Mud(SBM): A Study for Rheology Properties and Fluid Loss Control

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

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Approved by,

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TRONOH, PERAK

May 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or undone by unspecified sources or persons.

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(MUHAMMAD HAFIY AZIM BIN ABDUL AZIZ)

ABSTRACT

Synthetic based mud (SBM) has been widely used in drilling operation because of it good properties. But for the challenge in the future, operator companies might encounter with different behavior of well that will lead to a serious problem. It is believed that by using nanoparticles in drilling fluid, it will improve it properties such as rheology properties and fluid loss properties. Nano silica is among the candidates of nanoparticles that are expected to give positive result in both properties. In this study, the main focus is on the changes of characteristics of drilling mud by adding it with nano silica. The properties of drilling fluid might be improved or vice versa. Mud laboratory tests such as density, viscosity, gel strength and HTHP filtration were carried out from different range of oil-water ratio to get the suitability properties for drilling operation and level of safety. Initial test shows that by adding nanoparticles in drilling fluid, it gave positive result in the ability to reduce fluid loss rate. Therefore, this paper tried to prove that by adding nanoparticles in drilling fluid, the abilities of drilling fluid is going to be improved.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

The use of synthetic based mud (SBM) has increased significantly in drilling operation. SBM is known to provide excellent shale inhibition, lubricity, thermal stability, corrosion inhibition, borehole stability, tolerance of contamination and ease of maintenance. (Oehler et al., 1999) Currently ester is widely used in in oil and gas industry as a main based fluid for synthetic based mud. Player which is the operator company mostly dependent on this type of based fluid because it is suitable in all types of well.

Appropriate and optimize management strategies are required to sustain the development of oil and gas industries especially in petroleum operation. Maximum profits with optimum cost are the target most of the player which is the operator company in this industry even though they are implying new technologies to increase the production performance because that what their aims for every projects. Characteristic of the muds need to be improved as it will give benefits for the player. For example, damage caused by solid particles invasion especially will cause difficulty in term of cleaning the well. This issue has been recognized by industry and hence, at the first place the formation damage need to be prevent and put the cleaning the damage by strategic tools at second place. (Amanullah & Al-Tahini, 2009) Besides that, fluid loss might be an issue as it will affect the drag force during the drilling operation. Negative results such as increasing in cost operation and loss of time during drilling will impact the whole operation especially the operator company.

In this study, the standard based mud which is sarapar based will be used. And the mud will be added with nanoparticles which is nanosilica with different diameter with size of 5 to 15 nanometer and 10 to 20 nanometer. I will do study on the effect of nanoparticles on the different characteristics of synthetic based mud. The properties of that will be looking forward are the fluid loss, viscosity and basic rheology properties.

1.2 Problem statement

Synthetic based mud has been widely used by oil and gas industry specifically in drilling operation. As the future challenges that will come, study need to be done to improve the properties of the drilling fluid in order to fulfill the well desires. Hence, to investigate the early properties of drilling fluid by adding it with nanoparticles might be useful in the future study. Basic properties that will be done in this study are the rheology properties and the fluid loss control effect.

As the time passes, fluid loss during drilling might be the main issue during operation when operator encounter with more challenging wells in the future. It can cause loss of time and loss of money as we know. The cost when the drilling fluid loss always shows the capital expenditure for drilling operation and current analysis shows that it is kind of impossible to reduce the fluid loss by using micro and macro type of additives due to their properties that still falls short of the best that can be conceived (Zakaria et al., 2012). Nanoparticles have dramatically reduced the water flow into the formation (Sharma et al., 2012).

Hence, to reduce the fluid loss during drilling operation, this study will tell the usage of nanoparticle as a fluid loss agent and to determine the suitability of it. We have selected two chemical components for the fluid loss agent. Silicon dioxide with the particle size of 5 to 15 nanometer and 10 to 20 nanometer were selected. More than one chemical component is used because some chemicals give different result according to different condition and mud specifications. Some chemicals do not give same result if certain condition is applied even though they have same functions. Therefore the determination on which one is giving the best result should be done in order to reduce the fluid loss and minimize the operation cost.

1.3 Objective

The objectives of this study are:

- To investigate and analyze the rheology properties and viscosity of the mud by adding it with silicon nanoparticles.
- To study the effect of nanoparticles that give the best result in term of fluid loss control.
- To conduct an experiment and relate the result with an actual drilling mud.

1.4 Scope of study

This project is an experimental based study and can be divided into two parts. The first part of the project will be the preparation of the mud by mixing the chemicals compounds based on the formulation given. Second part of the project is by adding the different types of nanoparticle compounds in the mud. After that, the investigation of it rheology properties and effect of fluid loss control and compare with the actual drilling mud.

1.5 Relevancy of the project

To study the effect of nanoparticles in drilling fluid is relevant to the study of Petroleum Engineering as it explore the possibility of a new alternative to improve and enhance the properties of drilling fluid. Although the study of nanoparticles has been widen, but to know the exact effects of it in drilling fluid is still in the process of research. The design of the drilling fluid involves the concept of petroleum specifically in drilling concept.

1.6 Feasibility of the project within time scope and time frame

The time scope and time frame is referred as the project key milestone and gantt chart. 23 weeks are allocated for the student to accomplish their final year project, comprising of two semesters. The preparation of the project started with the collection of related materials for reading and understanding like books, journals and technical papers on mud formulation and nanoparticles. Throughout the schedule, research will be conducted from time to time in order to have a better insight of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Drilling fluid

Basically drilling fluids are a complex system and it consists of three different major types which are oil-based, synthetic-based and water-based which is will be added with several chemical and mineral additives (Amarc et al., 2011).

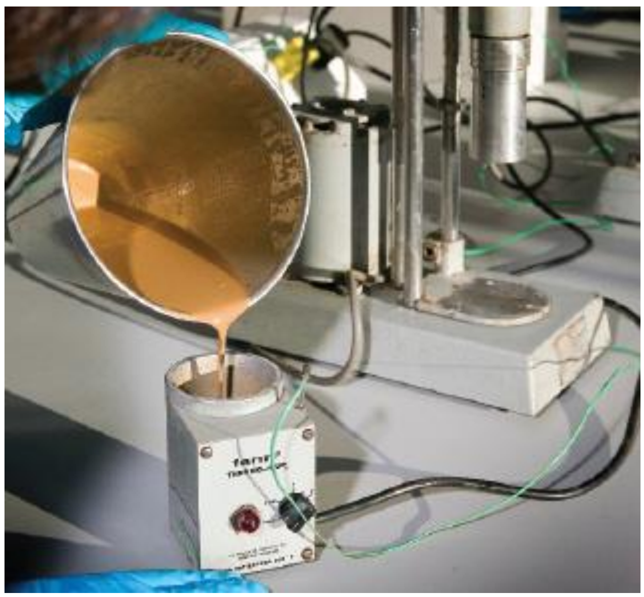

Figure 1: Sample of drilling fluid being poured in the thermo cup and heating jacket

There are many drilling fluids systems have been used in the oil and gas industry. For example freshwater, oil, saltwater, ester-based(SBM) and pneumatic(e.g foam, air) fluid system (West et al., 2006).

The term of 'mud' is always been used interchangeably with the term of 'fluid'. The term 'mud' because the fluid system is always have thick consistency (Caenn, 2011). What we know in general, the used of the drilling fluid is to assist tools during the drilling operation. The main functions of the drilling fluids are:

- Reducing the friction during drilling process

- Carrying the cutting chips from the hole to the surface
- Maintaining the pressure stability of the well bore
- Cooling the temperature of the drill bit
- Maintaining the down-hole hydrostatic pressure

In addition, drilling fluids also contain a different type of chemicals and usually they call it as additives. For each additive, they will give different purposes and for example:

- Inhibiting the corrosion of equipment (Amarc et al., 2011)
- Killing bacteria and adjusting the pH level (West et al., 2006)
- Controlling viscosity (Amarc et al., 2011)
- Reducing fluid loss to the formation (Amanullah et al., 2011)

Additives in the drilling fluids usually will be adjusted depending on the conditions of the geological formation which will change with depth. (Amarc et al., 2011)

2.2 Nanotechnology

Nanotechnology has been widely used by many companies for enhancing the quality of their products. There are hundreds of nano based products available in our world and most of them is in healthcare, coating industries and defense (Hoelscher et al., 2012) In the oil and gas industry, researchers from universities are trying to build something that can be benefit from the well exploration to gain the data from the reservoir which are the nanobot, nanosensor and nanomarkers (Hoelscher et al., 2013). Currently, the basic aim of using nanotechnology is to close the gap between the oil and gas industry and the nanotechnology community by using various ideas such as consortia between oil and service companies and nanotechnology excellence centres, networking communities, workshops and conferences, and even dedicated research units inside some oil companies. (Cocuzza et al., 2011)

Nanotechnolgy is used in drilling fluid as an additive has been investigated for few years by researchers and they have got mixed success result (Hoelscher et al., 2013). Because they want to solve the problems of drilling fluid, their desire to achieve the positive results has motivated them to look towards these nanotechnologies and see what they can get the benefits in the area of rheology properties and fluid loss.

Fluid loss control and rheology and are two areas of major basic to drilling fluid that appear to be related for the nanotechnology. From what has been stated above, due to the strong particles interaction, many nanomaterials can act as viscosifiers. (Friedheim, 2012). When one enters the area of drilling fluid, however the rheological effect that we want from an additive varies and it is depending on the goal whether it be the enhancement of hole cleaning (high low shear rate), the lessening of corresponding circulating densities with lower plastic viscosities and yield points, or the minimization of the effect that temperature has on viscosity (Hoelscher et al., 2013) . The table below will show few examples of the uses of nanotechnology in the oil and gas industry worldwide.

Table 1:Recent petro energy needs and solutions by using nanotechnology (Kong et al., 2010)

Area	**Industry Needs**	**Nanotech Solution**
Exploration	Less invasive methods of exploration, remote sensing Methods to "sniff" for new pockets of oil Enhanced resolution for subsurface imaging and computational techniques Improved temperature and pressure ratings in deep wells and hostile environments Improved instrumentation for gas adsorption Improved 1, 2, 3 and 4-D seismic resolution	Nanosensors and imaging
Reservoir management	Enhanced remote imaging, real-time continuous monitoring of flow-rate, pressure and other parameters during production, wireless telemetry Accurate early warning detection and location of leaks	Nanosensors

	Improved reservoir illumination and characterization including improved signal-to-noise ratio of subsalt events	
	Improved sand exclusion and mobility of injectant Controlled agglomeration of particles Ability to capture and store Carbon Dioxide	Nanomembrane
	Improved stability and pressure integrity and heat transfer efficiency Ability to minimize damage to formation of offshore platform, reduce the weight requirements and increase their sturdiness	Nanomaterials, fluids and coatings
Drilling	Increased effectiveness and longetivity of drilling components, making cheaper, lighter, stronger pipes and drill bits Extended lifetime of equipment with corrosion resistance, adhesion enhancement and wear resistance	Nanomaterials and Coatings
	Improved drilling fluids and thermal conductivity Removal of toxic metals (cadmium, lead, mercury) Ability to prevent drilling mud invasion, separating mud filtrate and formation water	Nanofluids and nanomembranes
Production	Increased wear resistance Self-feating materials Pressure integrity, improved robustness	Nanomaterials and Coatings
	Filtration of impurities from heavy oil and tight gas Sand exclusion Scale/wax removal Efective water-shutoff	Nanomembrane
	Environmentally friendly fluids Improved production rates and water disposition Reversible/reusable swellables High-strength/lightweight proppants	Nanofluids

2.3 Nanoparticles

A nanoparticle is defined as a tiny object that works as a whole unit in terms of its movement and characteristics. The size of nanoparticle itself is very small and it is billionth of meter smaller. General basic comparison has been made by comparing the size of our Earth to the size of a coin (Barr, 2009). In terms of diameter ultrafine particles are sized between 1 and 100 nanometers and it is by themselves or the manipulation of it to become the new large materials, where exclusive phenomena allow novel applications (El-Diasty & Ragab, 2013).

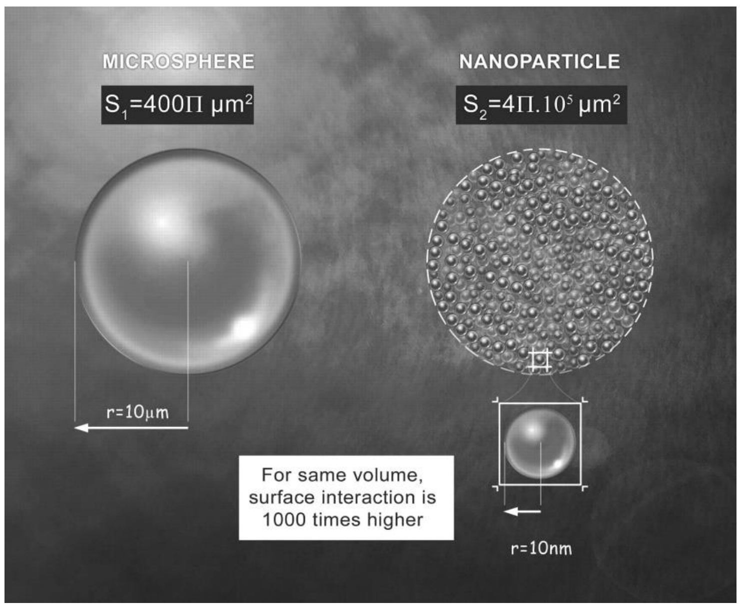

Figure 2:Comparison of size between nanoparticle and microparticle

Using of nanoparticles in drilling mud can be considered as one of the new technique in this drilling industry. Nanoparticles have create a new way to control the process of recovering oil that is unmatched by previous technology (Kong & Ohadi, 2010). The high surface area to volume of nanoparticles can give technical benefits for economic operation. The surface to volume ratio of nano-based mud additive expected to improve the thermal conductivity of nano-based fluid. Hence it will help in efficient cooling of drill bit leading to an increase in operating life cycle of drill bit (Amanullah et al., 2011). The recently latest developed nano-based fluids are formulated by using a blend of nanostabiliser to investigate the filtration and rheological properties.

Focusing on usage of nanoparticles in fluid loss control, study had indicated few positive results. The analysis show that the result of contents of the solids and the API fluid loss property of the nano-based fluids containing less than 0.5% nanoparticles with the bentonite mud containing 6.67% solids that shows very similar fluid loss behavior. This prove that the possible of superior fluid formulation using a tiny fraction of nanomaterials to produce same or better properties that can be achieved by using a significantly high concentration or low concentration of micro-sized mud additives in a mud system. The fluid loss properties of the mud can be enhanced in the future by adding it with conventional fluid loss additives or tailored made nano additives with larger plugging and sealing ability. (Amanullah et al., 2011)

Test has been carried out by Friedheim (2012), and the test show that by just adding nanoparticles of grapheme oxide to a fresh water slurry of bentonite and barite will give effect on viscosity. Table below shows this effect in terms of typical drilling fluid rheological parameters by adding 2 to 6 pounds per barrel of grapheme oxide to the slurry. The effect is quite substantial when only 2lb/bbl is added. The table below shows the test that has been conducted by Hoelscher.

Table 2:Addition of Graphene Oxide to slurry of barite and bentonite (Hoelscher et al., 2013)

Product	**Units**	**Test 1**	**Test 2**	**Test 3**	**Test 4**
Freshwater	ml	329	327	326	321
Gel	lb/bbl	5	5	5	5
Graphene Oxide	lb/bbl	0	2	4	6
Barite	lb/bbl	80	80	80	80
OCMA Clay	lb/bbl	10	10	10	10
Rheology Temperature	F	120	120	120	120

6-rpm Dial Reading	cP	1	4	11	17
3-rpm Dial Reading	cP	0	3	12	15
Gels 10-sec	lb/100 ft2	1	5	13	25
Gels 10-min	lb/100 ft2	2	6	13	14
Plastic Viscosity	cP	4	8	7	3
Yield Point	lb/100 ft2	-1	4	16	42

Silicon dioxide has been chosen for fluid agent control because it has the ability to withstand or resist high temperature in any condition. (Zheng et al., 2013). The melting point for silicon dioxide is more than 1,600 degree Celsius while its boiling point is at 2,230 degree Celsius (Aldrich, 2014). Certain study believe that this nanosilica particle can be plugging tools to decrease the penetration of water into the small sized pores shales. (Riley et al., 2012). The design of this mud had several factors that need to be considered such as the cost need to be economically attractive. Therefore the amount needed to be as low as possible to cut to operation cost. Besides that, the material needs to compatible with other mud additives without changing the mud rheology, result in good thermal stability and can resist or withstand contamination with solids.

2.4 Nanofluids

Nanofluids is one of these many innovative drilling fluids that have been made sometimes they called it as “smart fluid”, where nanoparticles are added to the drilling mud (Heraland et al., 2012). As for example, by using the nickel-based mud nanoparticles and adding it with drilling fluid, the observation showed that the coefficient of the friction can be reduced up to more than 25 percent (Heraland et al., 2012).

Recent experiments have showed that nanofluids have this one attractive properties for applications where heat transfer, drag reduction, binding ability for sand consodilation, gel formation, wettability alteration and corrosive control is of interest (Tran & Phuoc., 2007). A new method was presented to avoid stuck pipe or at any rate to reduce the probability while drilling of oil and gas wells using nanoparticles in drilling mud (Paiaman & Al-Anazi, 2009).

2.5 Drilling fluid formulation

One mud formulation has been created based on the data of the previous study, the mud formulation will be included with nanoparticles silicon dioxide as fluid loss agent during drilling operation. Below is the table of mud formulation for this study.

This study will be focusing at 275 degree F system. The result obtained will be compared with the previous mud and determine if there is any changes in its rheology properties as well as fluid loss properties.

Table 3:Proposed mud formulation

Functional Materials	275°F System	350°F System	450°F System
Base Oil	✓	✓	✓
Primary Emulsifier	✓	✓	✓
Secondary Emulsifier	✓	✓	✓
Viscosifier	✓	✓	✓
Other (XHT Viscosifier)		✓	✓
Fluid Loss Agent	✓	✓	✓
Lime	✓	✓	✓
Calcium Chloride	✓	✓	✓
Barite (4.2 SG)	✓	✓	✓
Barite (4.4 SG)		✓	✓
OWR	75:25	80:20	85:15
Mud Weight	12.0 ppg	13.5 ppg	17.0 ppg
Nano Silica Concentration		1 to 3 wt. %	

2.6 Theory

- 2.6.1 Basic Mud Testing

Basic mud testing is the fundamental steps to evaluate and conduct the test on the drilling fluid for this project. Basic mud testing includes the step by step procedures that need to be taken and to be followed. It includes the first step which is the preparing the chemicals which the weighting of the chemicals must be accurate. After that, the testing should include the mixing of the chemicals which need specific sequence. Then, the rheological test before and after hot-rolling should be done. Other than that, fluid loss test also should be done. (Styles et al., 2006)

- 2.6.2 Yield Point

In non-Newtonian fluid, a few characteristics of the fluids are needed to be determined. One of them is yield point. Yield Point is a function of the concentration of mud solids and their surface charges and potentials which affect inter particle forces. Dispersants and deflocculants are believed to adsorb on the mud particles. This action changes the chemical nature of the surfaces and likewise affects the inter particle forces, resulting in viscosity and YP reductions. (Styles et al., 2006)

- 2.6.3 Plastic Viscosity

Plastic Viscosity, μp is basically the proportional to rate of shear, thus largely reflects the resistance to flow. This situation is due to mechanical friction of the particles. The formula to calculate the plastic viscosity as stated above. Plastic viscosity is a function of solids‟ concentration and shape. It will be expected to increase with decreasing particle size with the same volume of solids. In oil muds, the plastic viscosity decreases with an increase in temperature or oil content. Besides that, we also can calculate the apparent viscosity from the data that will be obtained from viscometer. (Styles et al., 2006)

- 2.6.4 Gel Strength

The gel strength is one of the non-Newtonian rheological parameters. The unit of the gel strength is lbf/100 sq ft. gelling characteristics of the fluid can be determined from taking a 10 second and a 10 minute gel reading. Consequently there is no requirement to take a 30 minute gel under normal circumstances. However if increasing rheology is becoming a problem, a 30 minute gel should also be taken in order to determine the effectiveness of the treatment program. (Styles et al., 2006)

- 2.6.5 HTHP Filtrate Analysis

Generally, the results from the filtrate analysis will confirm the departure from normal of the values of yield point and gel strengths from rheological tests. Increases in mud volume due to liquid or gas intrusions should also be noted. Salt water flows are almost always accompanied by methane gas. Methane gas does not affect the chemical properties of either oil or water-based muds. Hydrocarbon gases can thin an oil-based mud through becoming dissolved in the base oil. (Styles et al., 2006)

CHAPTER 3: Methodology

3.1 Flow chart

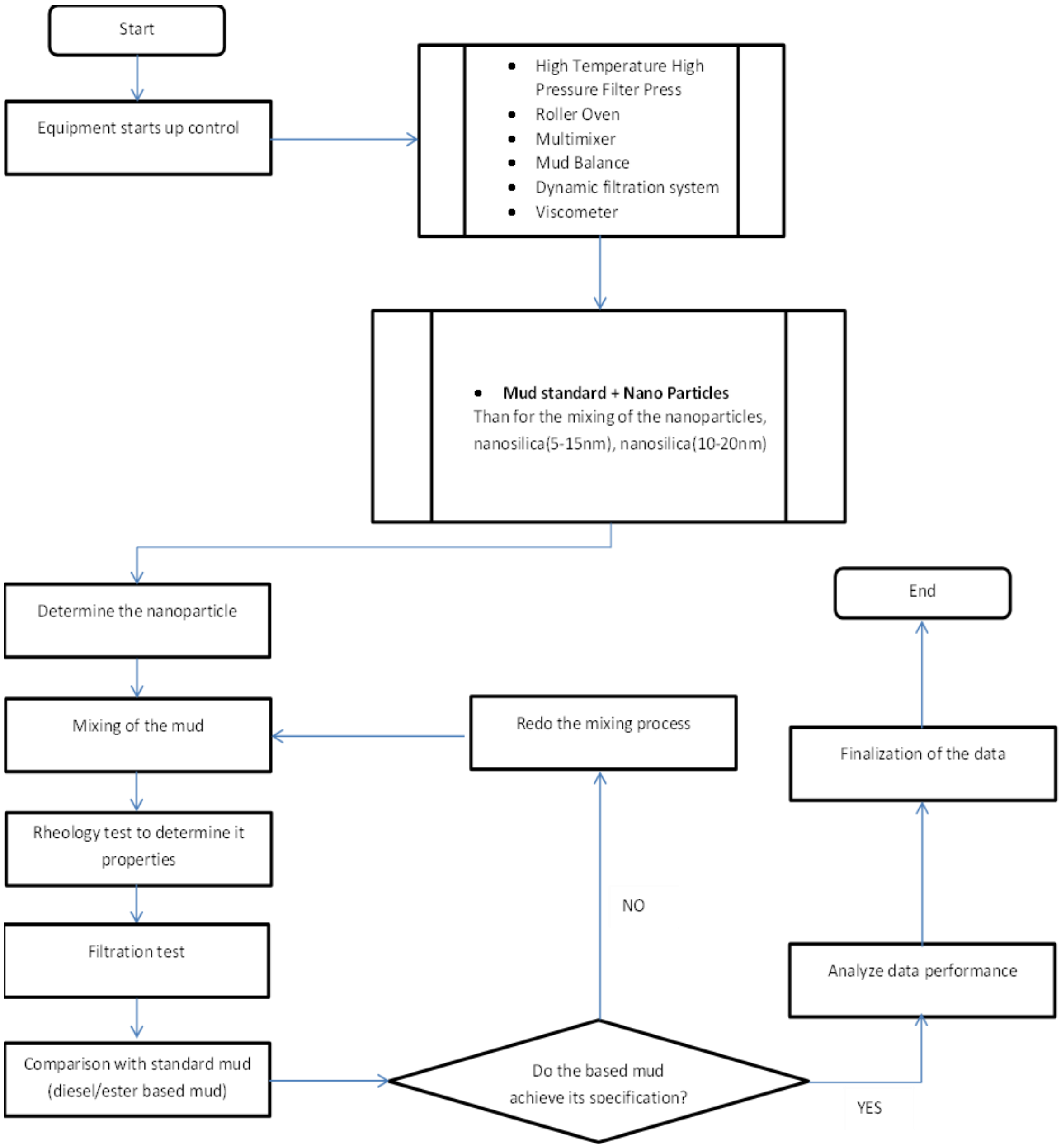

Figure 3: Flow chart to conduct this experiment

3.2 Flow process

Process 1:

This is the method where all the testing parameters to be determined. The samples preparation is basically based on:

- Base mud at 275°F
- Base mud + nanosilica at 275°F

Process 2:

In this process, all the samples were tested for:

- Early rheology properties and emulsion stability at normal temperature
- High pressure high temperature (HPHT) filtration test
- Hot rolled at designated temperature which is at (275°F) for 16 hours
- Aging test on rheology properties and emulsion stability as well as fluid loss properties

Process 3:

At this step, the comparison studies were done based on the given data for the required tests. An optimization process is going to be done, when the results that been obtained from the tests far beyond the required data.

Process 4:

The performance analysis on case-by-case basis was involved in this process. Each of the parameter will be analyzed in the results and discussion part.

Table below shows the mixing order and time for 275°F mud system, respectively.

Table 4:Mixing order and time for 275 degree F

Functional Materials	Mixing Order	Time, min
Base Oil	-	-
Primary Emulsifier	1	2
Secondary Emulsifier	2	2
Viscosifier	3	5
Fluid Loss Agent	4	5
Lime	5	2
Drill Water/Calcium Chloride	6	15
Barite (4.2 SG)	7	5
Drill Solids	8	5

The tables below show the mixing order to study the properties of fluid loss and viscosity of the mud by adding it with nanosilica at different order.

Table 5: Mixing order and time for base mud + 20% nanosilica for fluid loss

Functional Materials	Mixing Order	Time, min
Base Oil	-	-
Primary Emulsifier	1	2
Secondary Emulsifier	2	2
Viscosifier	3	5
Fluid Loss Agent	4	5
20% Nanosilica	**5**	**5**
Lime	6	2
Drill Water/Calcium Chloride	7	15
Barite (4.2 SG)	8	5
Drill Solids	9	5

Table 6:Mixing order and tie for base mud + 20% nanosilica for viscosity effect

Functional Materials	Mixing Order	Time, min
Base Oil	-	-
Primary Emulsifier	1	2
Secondary Emulsifier	2	2
Viscosifier	3	5
20% Nanosilica	**4**	**5**
Fluid Loss Agent	5	5
Lime	6	2
Drill Water/Calcium Chloride	7	15
Barite (4.2 SG)	8	5
Drill Solids	9	5

All of the samples have a total of 60 minutes mixing time, which include additional time. The mixing will be performed using the laboratory high speed mixer.

3.3 Gant chart

Table 7 : Timeline for FYP 2

No	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Mud formulation and mixing activity	■	●												
2	Data analyze for mud properties			■	●										
3	Rerun the mud formulation and mixing					■	●	●							
4	Submission of progress report								■						
5	Completing the final report								■	■	■				
6	Pre-SEDEX										■				
7	Submission of draft final report											■			
8	Submission of dissertation (soft bound)												■		
9	Submission of technical paper												■		
10	ViVa													■	
11	Submission of dissertation (hard bound)														■

3.4 Key milestone for FYP 11

Table 8:Key Milestone for FYP 11

No.	Description	Week No.
1	Started to mix the base case mud as a reference for the nanosilica mud	2
2	Calculated the new formulation for the mud with nanosilica	4
3	The nanosilica has arrived and mixed the mud with nanosilica	6
4	Mixed the different mud with new formulation to study other properties	7

3.5 Tools

- Multi Mixer
- Viscometer
- Mud Balance
- Heater Bath Tub
- HTHP Filter press
- Electric Stability Meter
- Basic Lab Equipment:
    - Beaker
    - Heater
    - Rolling oven
    - Separator funnel
    - Thermometer

CHAPTER 4

RESULT AND DISCUSSION

4.1 Result

There are 5 test that has been conducted for this experiment. They are:

- Test 1 = Base case mud
- Test 2 = Base case mud + 20% nanosilica (fluid loss)
- Test 3 = Base case mud + 100% nanosilica (fluid loss)
- Test 4 = Base case mud + 20% nanosilica (viscosifier)
- Test 5 = Base case mud + 100% nanosilica (viscosifier)

Result for the base case mud (test 1)

- Before hot roll

Table 9:Base Mud Properties Before Hot Roll

Rheology Characteristics	Result
600 rpm dial reading	78
300 rpm dial reading	46
200 rpm dial reading	36
100 rpm dial reading	25
6 rpm dial reading	9
3 rpm dial reading	9
Plastic viscosity, cP	32
Yield point, lb/100ft2	14
10' gel strength, lb/100ft2	8
10" gel strength, lb/100ft2	11
ES, volt	623

- After hot roll

Table 10:Base Mud Properties After Hot Roll

Rheology Characteristics	Result
600 rpm dial reading	80
300 rpm dial reading	45
200 rpm dial reading	33

100 rpm dial reading	20
6 rpm dial reading	6
3 rpm dial reading	5
Plastic viscosity, cP	35
Yield point, lb/100ft2	10
10' gel strength, lb/100ft2	6
10" gel strength, lb/100ft2	7
ES, volt	723

Other data beside rheology properties after hot roll

- Mud weight : 12 ppg
- HTHP (filtrate, ml) : 6
- Filter cake (mm/32) : 4

We will compare above result with the result when base mud mix with nanosilica to study the fluid loss properties. Below are the result for the base mud + 20% nanosilica(10-20 nanometer)

- Before Hot Roll

Table 11:Base mud + 20% nanosilica before hot roll for fluid loss

Rheology Characteristics	Result
600 rpm dial reading	48
300 rpm dial reading	29
200 rpm dial reading	22
100 rpm dial reading	14
6 rpm dial reading	5
3 rpm dial reading	4
Plastic viscosity, cP	19
Yield point, lb/100ft2	10
10' gel strength, lb/100ft2	12
10" gel strength, lb/100ft2	17
ES, volt	588

- After Hot Roll

Table 12:Base mud + 20% nanosilica after hot roll for fluid loss

Rheology Characteristics	Result
600 rpm dial reading	56
300 rpm dial reading	31
200 rpm dial reading	22
100 rpm dial reading	14
6 rpm dial reading	9
3 rpm dial reading	6
Plastic viscosity, cP	25
Yield point, lb/100ft2	6
10' gel strength, lb/100ft2	13
10" gel strength, lb/100ft2	22
ES, volt	592

Other data beside rheology properties after hot roll

- Mud weight : 12 ppg
- HTHP (filtrate, ml) : 5
- Filter cake (mm/32) : 2

Test 3 which is base case mud + 100% nanosilica for fluid loss.

- Before Hot roll

Table 13:Base mud + 100% nanosilica before hot roll for fluid loss

Rheology Characteristics	Result
600 rpm dial reading	57
300 rpm dial reading	34
200 rpm dial reading	25
100 rpm dial reading	17
6 rpm dial reading	10
3 rpm dial reading	8
Plastic viscosity, cP	23
Yield point, lb/100ft2	11
10' gel strength, lb/100ft2	13
10" gel strength, lb/100ft2	16
ES, volt	542

- After Hot roll

Table 14:Base mud + 100% nanosilica after hot roll for fluid loss

Rheology Characteristics	Result
600 rpm dial reading	61
300 rpm dial reading	37
200 rpm dial reading	24
100 rpm dial reading	18
6 rpm dial reading	11
3 rpm dial reading	9
Plastic viscosity, cP	24
Yield point, lb/100ft2	13
10' gel strength, lb/100ft2	14
10" gel strength, lb/100ft2	12
ES, volt	576

Other data beside rheology properties after hot roll

- Mud weight : 12 ppg
- HTHP (filtrate, ml) : 4.8
- Filter cake (mm/32) : 2.2

Next result by using the 20% concentration of nanosilica is to study the viscosity of the fluid. Below are the results.

- Before Hot roll

Table 15:Base mud + 20% nanosilica before hot roll for viscosity

Rheology Characteristics	Result
600 rpm dial reading	50
300 rpm dial reading	31
200 rpm dial reading	22
100 rpm dial reading	15
6 rpm dial reading	6
3 rpm dial reading	4
Plastic viscosity, cP	21
Yield point, lb/100ft2	10
10' gel strength, lb/100ft2	11
10" gel strength, lb/100ft2	16
ES, volt	636

- After hot roll

Table 16:Base mud + 20% nanosilica after hot roll for viscosity

Rheology Characteristics	Result
600 rpm dial reading	66
300 rpm dial reading	39
200 rpm dial reading	28
100 rpm dial reading	18
6 rpm dial reading	6
3 rpm dial reading	5
Plastic viscosity, cP	27
Yield point, lb/100ft2	12
10' gel strength, lb/100ft2	8
10" gel strength, lb/100ft2	11
ES, volt	533

Other data beside rheology properties after hot roll

- Mud weight : 12 ppg
- HTHP (filtrate, ml) : 7.2
- Filter cake (mm/32) : 6

Next result by using the 100% concentration of nanosilica is to study the viscosity of the fluid. Below are the results.

- Before Hot roll

Table 17:Base mud + 100% nanosilica before hot roll for viscosity

Rheology Characteristics	Result
600 rpm dial reading	96
300 rpm dial reading	56
200 rpm dial reading	45
100 rpm dial reading	31
6 rpm dial reading	14
3 rpm dial reading	13
Plastic viscosity, cP	40
Yield point, lb/100ft2	16
10' gel strength, lb/100ft2	19
10" gel strength, lb/100ft2	23
ES, volt	612

- After Hot roll

Table 18:Base mud + 100% nanosilica after hot roll for viscosity

Rheology Characteristics	Result
600 rpm dial reading	102
300 rpm dial reading	61
200 rpm dial reading	49
100 rpm dial reading	37
6 rpm dial reading	15
3 rpm dial reading	14
Plastic viscosity, cP	41
Yield point, lb/100ft2	20
10' gel strength, lb/100ft2	19
10" gel strength, lb/100ft2	23
ES, volt	521

Other data beside rheology properties after hot roll

- Mud weight : 12 ppg
- HTHP (filtrate, ml) : 5.8
- Filter cake (mm/32) : 4

4.2 Discussion and Analysis

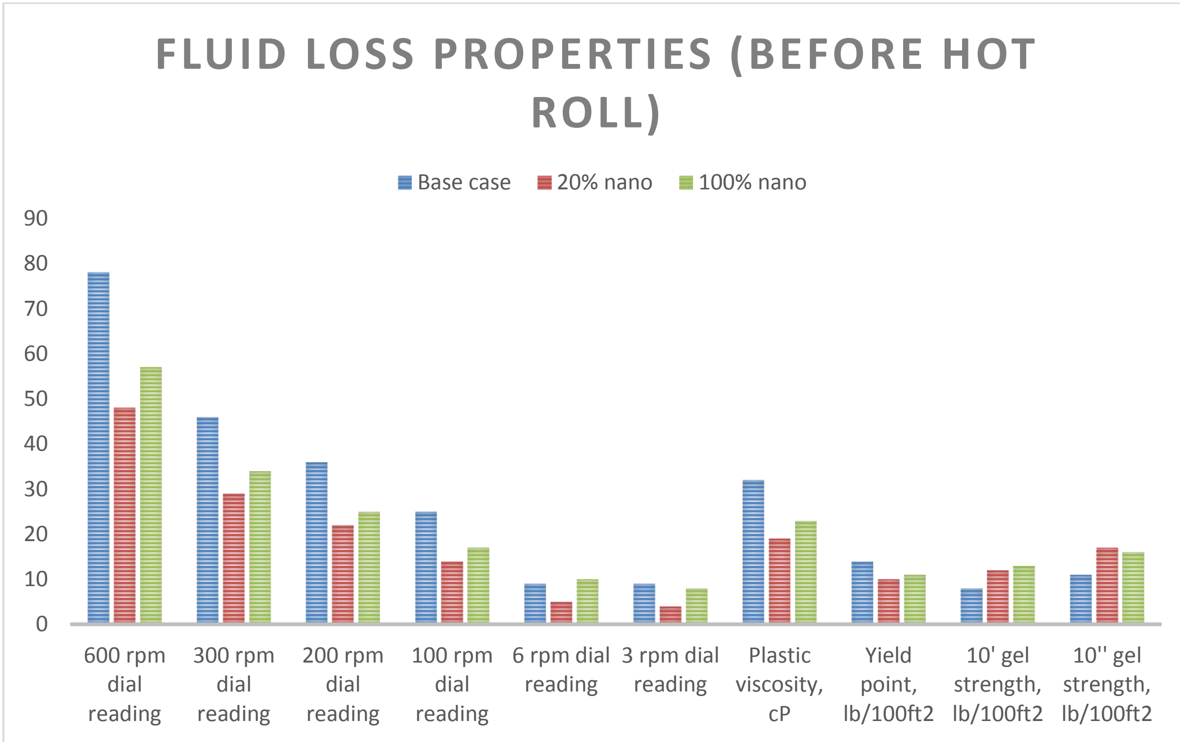

Figure 4:Graph of fluid loss analysis (Before hot roll)

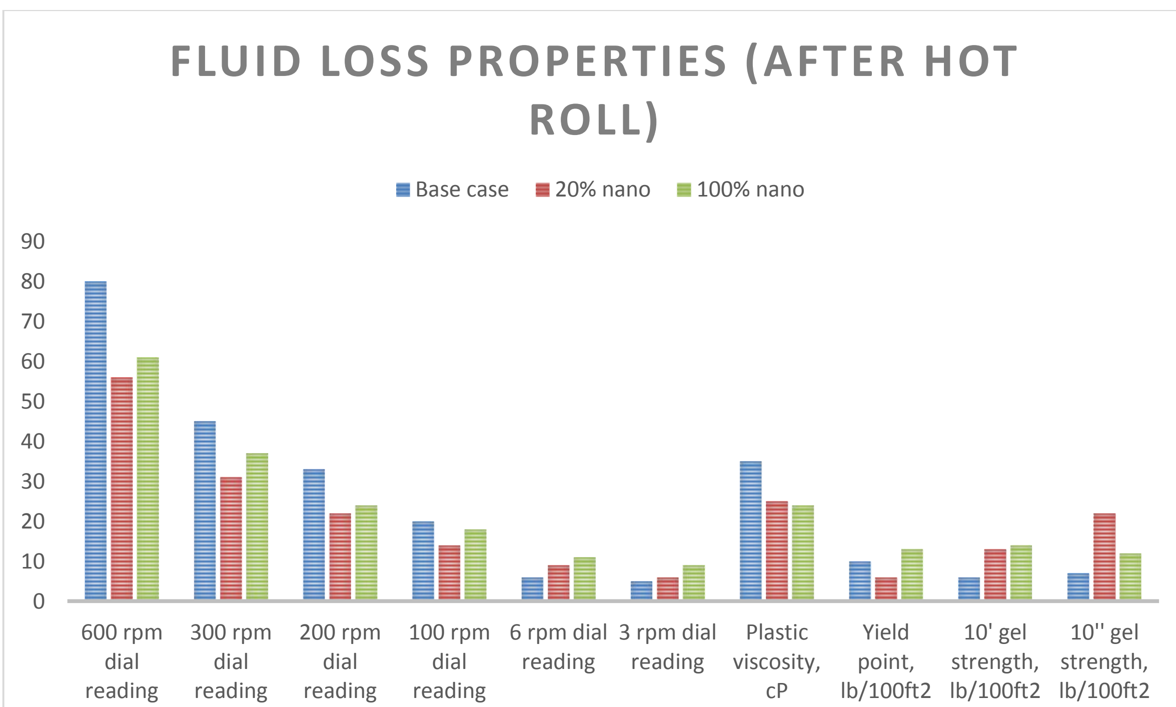

Figure 5:Graph of fluid loss analysis (After hot roll)

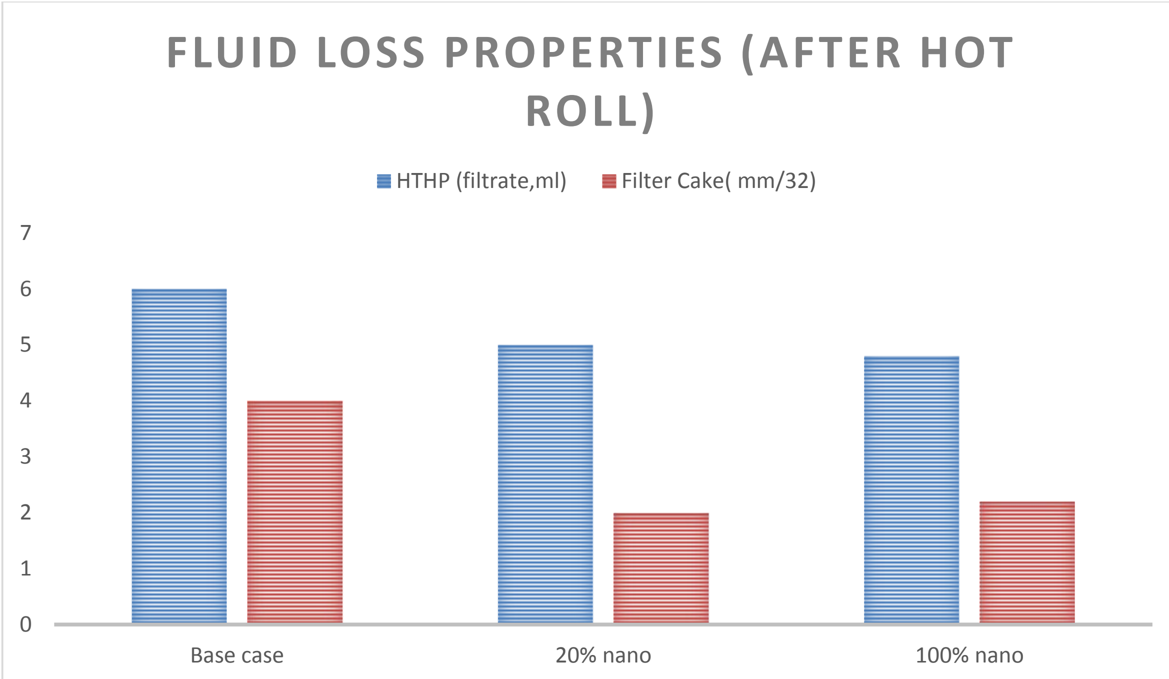

Figure 6:Graph of fluid loss analysis for filtrate and filter cake (After hot roll)

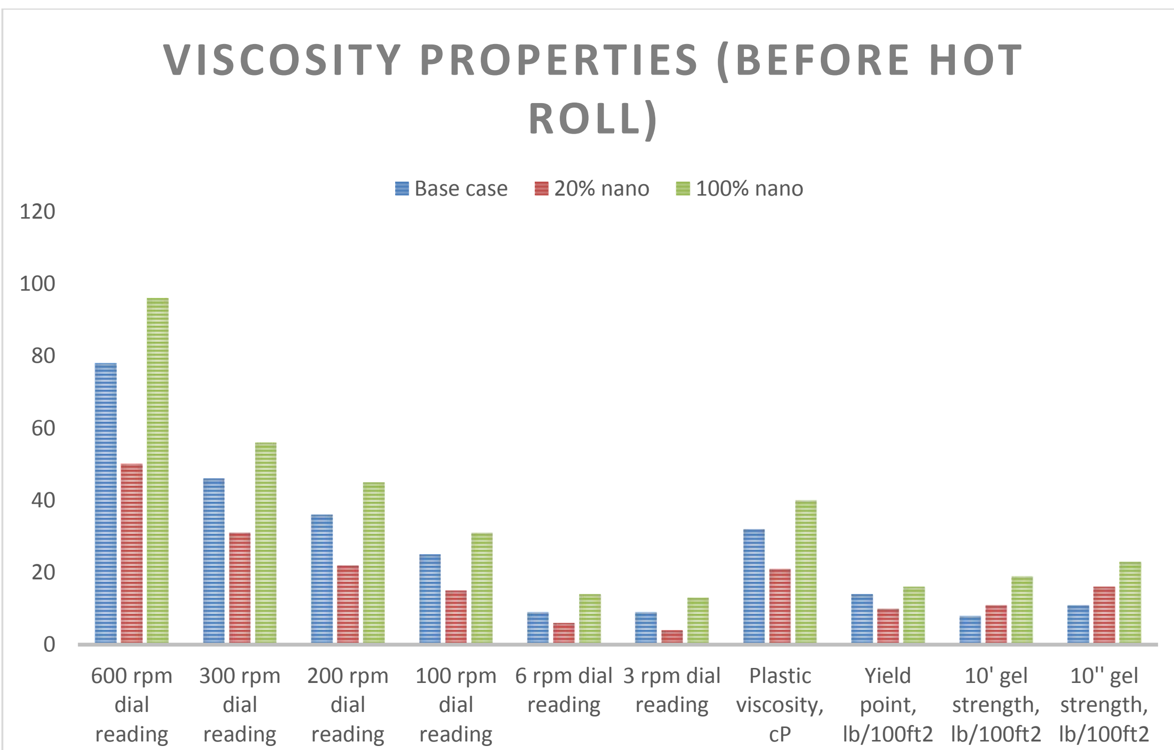

Figure 7:Graph of viscosity analysis (Before hot roll)

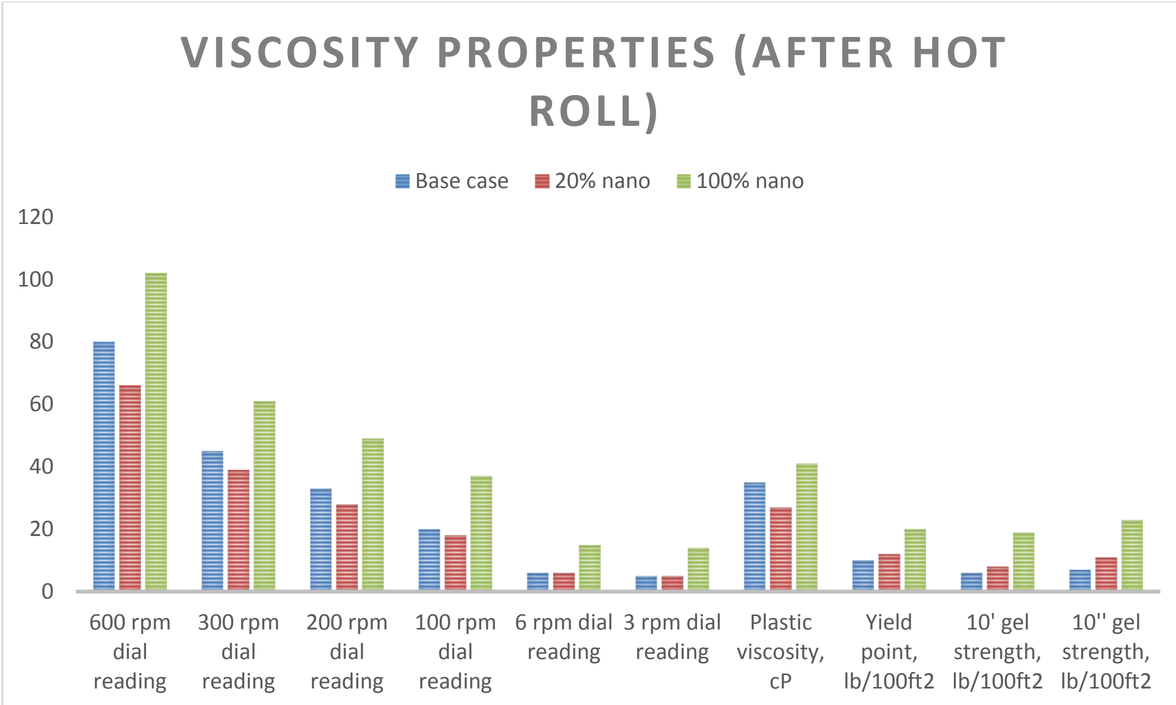

Figure 8:Graph of viscosity analysis (After hot roll)

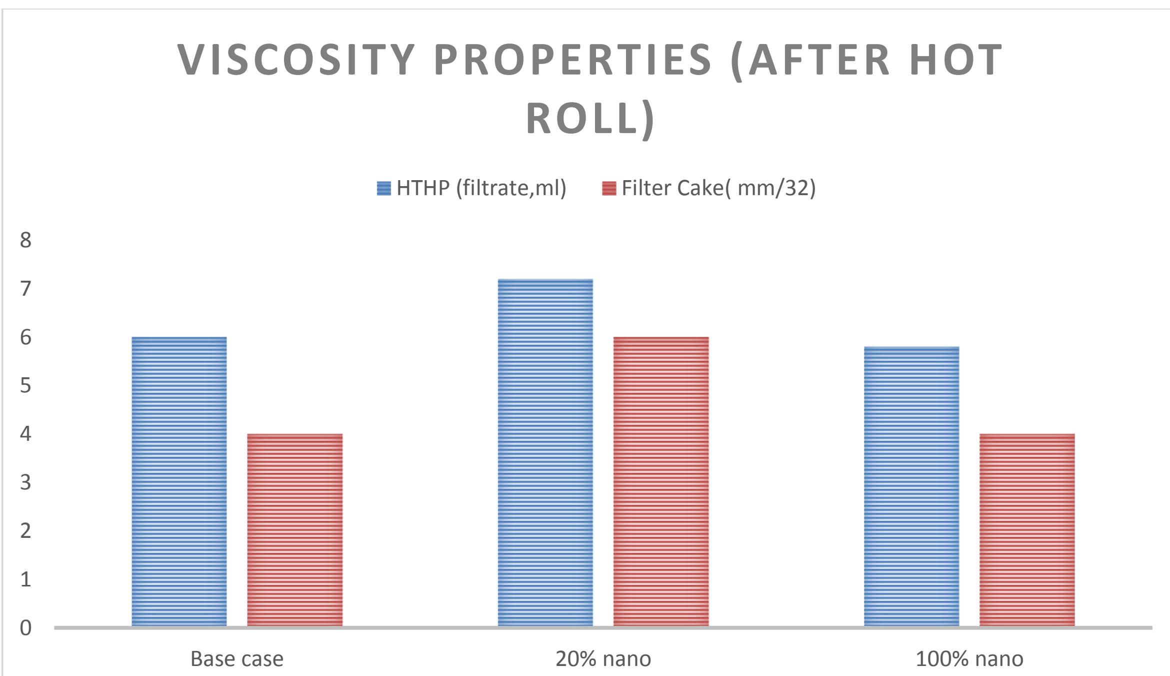

Figure 9:Graph of viscosity analysis for filtrate and filter cake (After hot roll)

- Fuid loss result

From figure 6, we can see that muds that have fluid loss control additives give the lowest value of filtrate loss collection. Which is the mud with 20% of nanosilica. This is because in this base muds there is chemical that act as prevention chemicals to control the fluid loss and it is significantly that we need fluid loss control additives in drilling fluids. This is due to the different way of mixing order and it is to control the viscosity. Thus, the result is as what been expected. On the other hands, mud with 100% of concentration of nanosilica gives almost the same result with the other two samples. This is maybe due to the effect of the nanosilica when it exceeds the optimum concentration doesn't give any effects towards the mud. Hence the effect of nanosilica towards the mud can be said as positive because at 20% of concentration, the result is as what that has been expected from the objective. It can be conclude that by using nanosilica in the mud, there must be an optimum concentration that will give the best result for filtrate and fluid loss. We also can see that, the mud with additives gives highest value of fluid loss.

- Viscosity result

To study the effect of nanosilica in viscosity, we refer to figure 7 and figure 8. The base mud mixed with 100% concentration of nanosilica gives the highest value of plastic viscosity which is 41cP (after hot rolled). While the lowest value of plastic viscosity is for base mud + 20% nanosilica which is 27 cP (after hot rolled). For both of the result, we can clearly see that by adding nanosilica as viscosifier give a result that not what been expected. Too high viscosity will give problem to the drill bit to rotate and it is hard to send cutting chips. We can conclude that, nanosilica is not suitable for viscosifier agents in drilling fluid. We might want to improve the data in term of concentration of nanosilica.

- Economic Analysis

The successful completion of an oil well and its cost is depend to a considerable extent on the properties of the drilling fluid. The cost of the drilling fluid itself is relatively small, but the choice of the right additives of the right properties while drilling greatly influence the total well costs. Drilling means money, therefore each and every decision taken in oil and gas industry must be very careful and effectively to the industry.

4.3 Error Analysis

In this experiment, there are a few human errors. The first one may be the accuracy while weighting the chemicals. Sometimes the readings are not really accurate and it can be affected by the surrounding such as air flow.

The next error is parallax error while taken the measurement of rheological properties and also the fluid loss collected. While taking the rheological values, the indicators sometimes move too fast and the measurement are based on assumptions.

The reading of fluid loss collected in the measurement cylinder can be fault due to the eyes condition. The eyes and the meniscus should be parallel in order to get accurate value.

Besides that, the mud itself sometimes is not mix properly. This is due to the mixing time. Sometimes the muds are mixed too long and sometimes too short in time.

Another error would be the machine error. For this experiment, there are a lot of equipments used such as Viscometer, HTHP Filter Press, ES meter and others equipment. Sometimes, the equipments itself are not working properly or perhaps it has not been calibrated yet before the testing. Due to this, the values obtained from the equipments can be not really accurate.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, from the result that had been collected, we can see the differences between all three types of muds in term to study of fluid loss. All of them give different values but very close to each other. From the result, nanosilica has the potential to be proved to be good additives in helping to reduce fluid loss in the muds in correct amount of concentration. While for viscosity, in my opinion nanosilica is not a suitable candidate to replace industry viscofying agent as the result is not giving any improvements. Even there is still changes in result, nanosilica is quite expensive if we want to make it as viscosifier.

All in all, this project is done within the time frame and the progress is good. All of the objectives stated below have been achieved which are:

- To investigate and analyze the rheology properties of the mud by adding it with silicon nanoparticles.
- To study the effect of nanoparticles that give the best result in term of fluid loss control.
- To conduct an experiment and relate the result with an actual drilling mud.

Nanoparticles alone can effectively plug the pore to prevent the fluid loss during drilling. As the fluid losses during drilling reduce, the cost of the operation and time will reduce. It will give benefits for the operator to operate the well. For the future study, nanoparticle used to prevent drilling fluid invasion into the formation. More studies are needed with nanomaterials and their application in the area of drilling operation.

5.2 Recommendation

- HPHT Temperature Control

While doing this experiment, the temperature for HPHT filter press cannot be set accurately because the knob only shows toward a number (1 to 9) and not temperature. So, if the temperature is desired for example 250^0F, the user gets confused which number should be referred to. Thus, it would be advisable to introduce a dial or knob that been able to set the temperature directly and not to be play around with the numbers.

- Nanomaterial

It is highly recommended to try using various types of nanomaterial such as nanographene or nanocarbon, because the result might be different, maybe it will be much better. Besides that, this might help in future study of nanomaterials effect in oil and gas industry.

- Concentration

By using different concentration such as 40%, 50% or 60%, maybe we can get the desire result or optimum result for nanosilica can be used in drilling fluid.

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Appendices