STUDY THE EFFECT OF SILICA NANOPARTICLE ON RHEOLOGY IN OIL BASED MUD

by

Mohd Fareez Bin Mustapha

A dissertation submitted in partial fulfillment of
the requirement for the

Bachelor of Engineering (Hons)

(Petroleum Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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PETROLEUM ENGINEERING

Approved by,

____

(Dr. Sonny Irawan)

UNIVERSITI TEKNOLOGI PETRONAS

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JANUARY 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 done by unspecified sources or persons.

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(MOHD FAREEZ BIN MUSTAPHA)

ABSTRACT

Limitations of conventional drilling fluid with macro and micro size are not suitable for extreme environment in drilling or completion operation. Macro and micro type fluid additive is impossible to fulfil challenging drilling and production operation requirement due to their inadequate physical, mechanical, chemical, thermal and environment characteristic. Introduction of nanotechnology in oil and gas industry produce a promising nanoparticle which are able to satisfy the requirements; physically small, chemically and thermally stable to design a smart fluid. This project will determine the effect of silica nanoparticle on rheology in oil based to analysis the changes the rheology properties of drilling fluid with and without silica nanoparticle after and before aging process. The ability of silica nanoparticle as an additive in drilling fluid will be evaluate through a few experiments; rheology and high pressure high temperature (HPHT) fluid loss test. Analysis of experiments results will determine the suitability of silica nanoparticle to be used in oil based mud. As a final result, combination of silica nanoparticle in oil based mud enhances the rheology of oil based mud compare to the oil based mud without silica nanoparticle.

ACKNOWLEDGEMENT

Thank to Allah for give me an opportunity to express my profound gratitude and deep regards to my supervisor (Dr Sonny Irawan) for his exemplary guidance, monitoring and constant encouragement throughout the final year project I and II. Help and guidance given by him from time to time make the author enable to complete this final year project successfully with a lot of experiences and new knowledge in oil and gas industry generally. Despite his busy schedule, he has guided and supervised me in ensuring the progression of my final year project.

I also take this chance to express a deep sense of gratitude to En. Jukhairi (Technician) for his guidance and cooperation in doing experiments. He stimulates suggestion and encouragement that helped me to complete this project by showing the various tests, instrument used, and work flow involved in the experiment of this project.

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CHAPTER 1

INTRODUCTION

1.1 Background

Advance technology in oil and gas industry trigger a lot of idea for improvement of life span of wells and amplify the ability to reach extreme condition with huge reduction of cost. The successful of drilling operation depends on the drilling fluid used. Precise selection of drilling fluid will significant in cost reduction and maximize of profit. Increasing of competitor in oil and gas industry to develop new technology in drilling and production operation gives an impact to the economy of drilling since it increases the non productive time (NPT).[13] In this research, application of nanoparticle in drilling fluid offers a high confidence to operator to maximize their profit by reducing overall cost. Combination of nanoparticle additive with drilling fluid gives a significant effect in drilling operation especially in extreme condition by reduce all the possibility of failure. Emerging of nanoparticles in production and exploration (E&P) operations give a huge impact in several aspect of oil and gas industry in term of potentially and economically. Nanotechnology can offer many potential solutions to resolve industry problem for upstream sector that cannot be solved with traditional approaches.[18]

Nanotechnology has numerous applications in a variety of industries such as healthcare, defense and coating industries. The ability of nanotechnology to produce tailored made nanomaterials with specific properties is expected to play a leading role in overcoming the technical and environmental challenges faced during petroleum development and production.[18]Nanoparticle widely use in world industries basically have a size less than 100 nanometer (nm) in dimension of structural radius, but in some new applications use particle of a few hundred nanometers. Nanoparticles have different physical properties from micro particles. As the size decrease (from microparticle to nanoparticle) the ratio of the surface area to volume and particle movement into the realm will increase. The effects from the larger surface area of nanoparticles form special properties such as increased strength and/or increased chemical/heat resistance. Dimension of nanoparticles which are below the critical wavelength of light turn them to transparent. Addition of nanoparticle in drilling fluid did not affect the weight of drilling mud because of its negligible weight. Characteristics of nanoparticle as drilling fluid additive will give a great contribution to encounter technical problem in drilling operation.

Success of drilling operation depends mostly on drilling fluid used. Drilling fluids are designed to perform efficiently under unexpected wellbore condition. Drilling fluid commonly has two types which are water based mud (WBM) and oil based mud (OBM).

The main function of drilling fluids can be summarized as follows;

I. Remove cutting from the well
II. Suspend and release cuttings
III. Control formation pressure
IV. Seal permeable formation
V. Maintain wellbore stability
VI. Minimizing formation damage
VII. Cool and lubricate the drill bit

Drilling fluid impairment with formation can cause formation damage due to combination of several mechanisms such as solid plugging, swelling of clay formation, saturation changes, wettability changes, emulsion blockage and filtrate blockage. Water invasion from WBM enter the formation and reduce the reservoir potential. Swelling of clay formation such as smectite and illite will reduce the porosity and permeability or totally block pores throat. Failure to select proper type of drilling fluid can cost severe wellbore problem. Drilling fluid and drilling filtrate may cause formation damage due to fines migration, rock wettability changes, drilling fluid solids plugging, and formation water chemistry incompatibilities.

Oil based mud (OBM) made up of oil as the continuous phase. OBM typically used because they have low water reactivity which will prevent swelling of clay composition inside formation. The advantages of OBM are high drilling rate, lowered drill pipe torque and drag, less bit balling and reduce differential sticking inside the wellbore. Oil based mud is high unit cost and decision to use OBM need a thoroughly consideration to avoid from wasting of time and money. Water based mud (WBM) is a drilling fluid which water act as continuous phase. WBM may be classified in four groups which are dispersed – non inhibitive, dispersed – inhibitive, non dispersed – non inhibitive and non dispersed – inhibitive. WBM offer the benefits of environmental compliance, attractive logistic and a relatively low unit cost compare to OBM. Evaluation of drilling fluid properties will ensure the effectiveness in drilling operation. Consideration of drilling fluid properties must be parallel to formation thus minimizing the possibility of damage inside the wellbore. Drilling fluid properties are mud density, viscosity, plastic viscosity (PV), gel strength, yield point and fluid loss. Different drilling fluids have different properties. Enhancement of drilling fluid properties can be done by adding necessary additive to increase their ability to operate under unpredicted condition of formation.

1.2 Problem Statement

Formation damage caused by the particles from drilling fluid into the formation can severely reduce the well productivity. Solid content in drilling fluid can damage the formation of wellbore through invasion of solid particle that penetrate inside the pore. Pore plugging causes by particles reduce the permeability and finally make the well become uneconomic to produce. Fluid loss and mud cake quality produce from drilling fluids play a crucial role to prevent solid from drilling fluid to penetrate inside the pores and consequently reduce or damage the permeability of the formation. Implementation of nanoparticle as a drilling additive will influence the quality and performance of drilling fluid compare to conventional drilling fluid.

1.3 Objective

This research aimed to study the properties of the new additive of drilling fluid by using silica nanoparticle and compare it with conventional drilling fluid (without silica nanoparticle). The details of the objective are as follows:

1. To evaluate and compare the rheology between conventional oil based mud and modified oil based mud (silica nanoparticle enhancement) and its suitability in high pressure high temperature well condition.
2. To determine the fluid loss and mud cake thickness in high pressure high temperature (HPHT) drilling fluid with silica nanoparticle additive and conventional drilling fluid (without silica nanoparticle)

1.4 Scope of Study

This research will focus on mud rheology of drilling mud with and without silica nanoparticle to measure the effectiveness of this additive in drilling fluid. Mud rheology characteristics; viscosities, gel strength, yield point, fluid loss in HTHP, mud weight and emulsion stability are required to determine the effect of silica nanoparticle in oil based mud. This project consists of two parts of experiment; before and after hot rolling process. The rheological behavior is to indicate the performance of drilling fluid in hole cleaning and hole erosion, suspension of drill cutting, hydraulic calculation, fluid loss, and requirement of drilling fluid treatment in HTHP wells. The viscosity is focusing on plastics viscosity to indicate the drilled cuttings suspension and hole cleaning abilities under dynamic condition.

1.5 Relevancy of Research

The application of nanotechnology in oil and gas industry especially in drilling mud creates total evolution in order to create higher success rate in drilling wells. This research can be a platform to enhance conventional drilling mud with nanomaterial additives and reduced the overall cost and time consuming of drilling and production operation. This research basically study the mud rheology of drilling mud with or without nanoparticle and make a comparison and analysis the influence of silica nanoparticle toward the problem related to wellbore failure especially formation damage

1.6 Feasibility of Research

This research is feasible to complete within the timeframe which in 2 semesters. This project requires execution a number of laboratory tests that could be done at Universiti Teknologi PETRONAS (UTP) laboratories or at any other drilling fluid laboratory outside the university. All these methods and equipments needed are feasible and available to achieve objectives of the project within the proposed time.

CHAPTER 2

THEORY AND LITERATURE REVIEW

2.1 Nanoparticle

Advancement of technology leads to explore critical areas which are impossible to reach due to the limitation of technology. Involvement of nanotechnology in oil and gas industry creates a new opportunity to maximize as much as possible oil and gas beneath the earth. Technical problems face during extreme drilling operation formation trigger new ideas to modified drilling fluid with nanotechnology. As the technology become more sophisticated, new formula is needed for existing drilling fluid to adapt this high technology.

Evolution of nano technology affect oil and gas industry as the drilling and production operation become more sophisticated with a lot of technical challenges due to a change in the operational depth, nature of subsurface, shape of wellbore profiles and more. Applications of nano particles in this industry generate a lot of possibility to increase production rate of oil and gas.

Nanotechnology has numerous applications in a variety of industries such as healthcare, defence and coating industries. Nanoparticle widely use in world industries basically have a size less than 100 nanometer (nm) in dimension of structural radius, but in some new applications use particle of a few hundred nanometers. These particles are smaller than micro particles, have a high surface to volume ratio and may provide superior fluid properties at low concentration of the additive.[33]The large surface area of nanoparticles also results in a lot of interactions between the intermixed materials in nanocomposites, leading to special properties such as increased strength and/or increased chemical/heat resistance.[14]

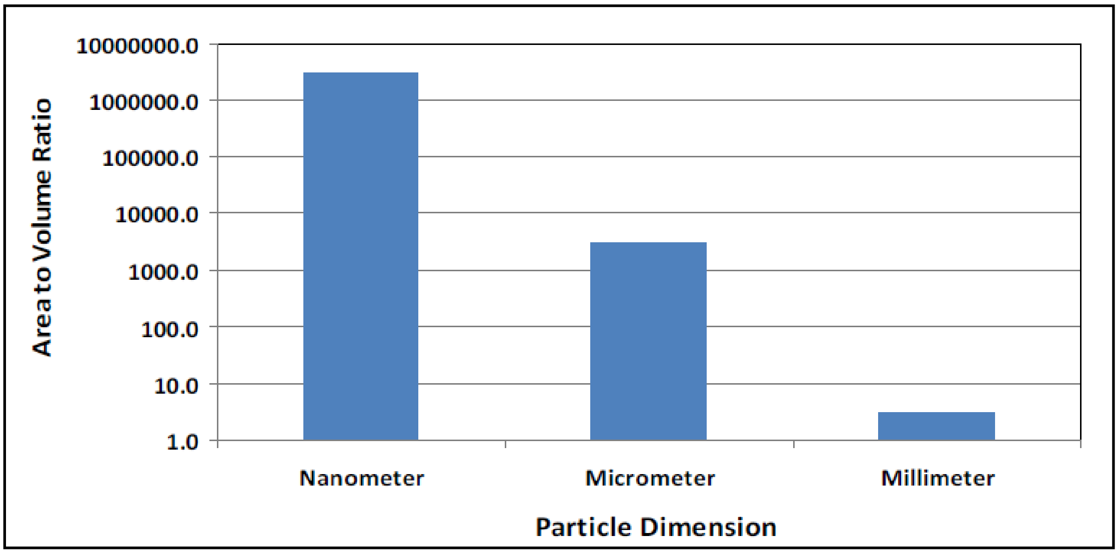

Figure 1: Surface area to volume ratio of same volume of materials[1]

2.2 Drilling Fluid

Drilling fluid or drilling mud is the mixture of 3 elements which are clays, chemical and water. Drilling fluid is pumped down the borehole to aid drilling operation to perform the necessary function;

I. Remove cutting from the well.

II. Suspend and release cuttings.

III. Control the formation pressure of the well.

IV. Maintain wellbore stability.

V. Minimizing formation damage.

VI. Cool, lubricate and support the drill bit and drilling assembly.

VII. Seal permeable formations.

VIII. Facilitate cementing and completion operation.

Typically there are two type of drilling mud; 1) Water based mud. 2) Oil based mud. Water based mud (WBM) is a drilling fluid which water act as continuous phase. WBM may be classified in four groups which are;

I. Non-dispersed-Non - inhibited

II. Non-dispersed - Inhibited

III. Dispersed - Non-inhibited

IV. Dispersed – Inhibited

Oil based mud (OBM) made up of oil as the continuous phase. Commonly oil based mud particularly useful in shales and water sensitive formation. OBM typically used in shale formation because they have low water reactivity which will prevent swelling of clay composition inside it.

The advantages of OBM are high drilling rate, lowered drill pipe torque and drag, less bit balling and reduce differential sticking inside the wellbore. Oil based mud are more cost effective than water based mud in following condition:

I. Shale stability

II. Temperature stability

III. Lubricity

IV. Corrosion resistance

V. Stuck pipe prevention

VI. Contamination

VII. Production protection

In this project, oil based mud is used to compare the mud properties between two different formulation of mud (with and without silica nanoparticle additive). Oil based mud require special products to ensure that the emulsion is extremely stable and can withstand conditions of high temperature and contaminants. Every single product must be dispersible in the external oil phase.

Table 1: Main chemicals to prepare oil based mud.[3,4,7,9]

Emulsifying Systems	Calcium soaps are the primary emulsifier in oil muds. These are made in the mud by reaction of lime and long chain fatty acids. Soap emulsions are strong emulsifying agents but may take reaction time before emulsion is actually formed. Thus secondary

	emulsifiers are used: they consist in very powerful oil wetting chemicals which generally do not form emulsions but wet solids before the emulsion is formed. Also used to prevent from any water intrusion.
Lime	Lime is essential in oil based mud. It neutralizes fatty acids in the fluid, stabilizes the emulsion when present in excess, and control alkalinity. In the field, it also neutralizes acid gases (H_2S and/or CO_2).
Fluid Loss Reduction Additives	Many types of chemicals can be used as Fluid Loss control agents. They are usually organophiliclignites (amine-treated lignites), Gilsonite or Asphalt derivatives, or special polymers (polyacrylates…). The impact of such products on rheology depends on their nature. For instance, lignites (even used at high concentration) do not affect viscosity, whereas asphalt derivatives can cause excessive viscosity and/or gelation
Wetting Agents	Supplemental additives to quickly and effectively oil-wet solids that became water-wet.
Chemicals to control rheology	Additives that build the viscosity of the mud. Bentonite, hectorite or attapulgite, treated with amine to make them oil dispersible, are the commonly used organophilic gallants. When their properties are reduced by high temperature, polymeric viscosifiers are added. Other rheological modifiers increase the viscosity at low shear without increasing total mud viscosity, e.g. low molecular weight fatty acids. Deviated wells are good conditions of use for such products.
Weighting agents	Used to increase the density of the oil mud. The most commonly used are calcite, barite, and hematite.

2.3 Formation Damage

Drilling fluid impairment with formation can cause formation damage due to combination of several mechanisms such as solid plugging, swelling of clay formation, saturation changes, wettability changes, emulsion blockage and filtrate blockage. Water invasion from WBM enter the formation and reduce the reservoir potential. Swelling of clay formation such as smectite and illite will reduce the porosity and permeability or totally block pores throat. Drilling fluid and drilling filtrate may cause formation damage due to fines migration, rock wettability changes, drilling fluid solids plugging, and formation water chemistry incompatibilities. Failure to select proper type of drilling fluid can cost severe wellbore problem.

Differential sticking problem is one of the high costs in oil and gas industry. It is responsible for lost rig time, tubulars, downhole equipment and tools as well as sidetracks, and substantially increases drilling costs during one of the most cost conscientious periods in our industry's history.[5] These phenomenon occur when the drill string is embedded in a mudcake with poor quality and characteristic that forms an impermeable wall to prevent loss of fluid into the formation.

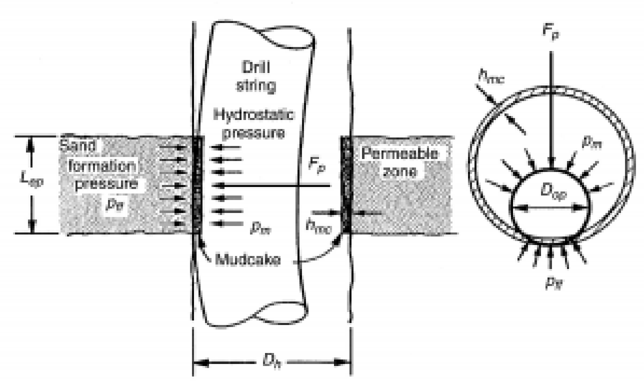

Figure 2: Mechanism of differential sticking problem. [6]

According to Bland, Micho, & Howard, (1992) "A portion of the drill string will always be in contact with the side of the hole especially in deviated wells. The drill string is lubricated with a film of drilling fluid as long as the string is moving and the distribution of pressure around the drill string is equal. A pressure differential develops when motion ceases and the filter cake between the drill string and a permeable zone is isolated from the drilling fluid column and begins to lose pore water to the formation. Friction increases between the drill string and the dehydrating and compacting cake, resulting in increasing torque and drag. Once drag exceeds the power of the rig, the drill string is stuck."

Isambourg, E.P, Ottesen, Benaissa, & Marti, (1999) stated that:

The necessary pull out force to unstuck the pipe will depend on the differential pressure an on the cake strength at time of the attempt to liberate the pipe. The rate of the cake pore pressure will depend on the cake permeability once compacted. Thus, parameters that govern the differential pressure sticking are:

I. Mud to formation over pressure
II. Compacted mud cake permeability
III. Compact cake “hardness”
IV. Exposure time

Good quality of mud cake can reduce the differential sticking problem. Application of silica nanoparticle as an additive in oil based mud can reduce the permeability of mud cake in borehole wall and reduce the differential sticking problem and save overall cost for drilling and completion operation.

Wellbore instability is one of the main problems in drilling operation and can be classified into two major causes which are mechanical and chemical effects. Borehole instability is mainly caused by the fluid invasion into the shale formation. Shale have high tendency for borehole instability problem. Conventional drilling fluids are difficult to operate effectively in shale formation because of its nanopores. Invasion of fluid into the nanopores increase the pore pressure inside it and create instability to the borehole. Silica nanoparticles which have nano size have the ability to plug the nanopores of shale and prevent invasion of drilling fluid and reduce the borehole instability problem.

Drilling fluid with nanoparticles additive is category as nano fluids. According to Md. Amanullah & Al-Tahini, (2009), “Nano fluids are defined as any fluids (drilling fluids, drill in fluids, etc) used in the exploitation of oil and gas that contain at least one additive with particle size in the range of 1-100nm. The main application of nanoparticles would be to control the spurt and fluid loss into the formation and hence control formation damage. The presence of nanoparticle can lead to better sealing at an earlier stage of filter cake formation and, subsequently, a thinner impermeable mud cake. Due to its high surface to volume ratio the particles in the mud cake matrix can easily be removed by traditional cleaning systems during completion stages.”

Increase in exploration and exploitation cost which mainly focus on deep water compare to onshore and shallow water lead to increasing of production cost with lower return on investment. To prevent drilling and production problem is the main priority rather than treat them. According to Md. Amanullah & Al-Tahini, (2009)“The conventional macro or micromaterial-based drilling, drill in, completion, stimulation fluids have limited success in solving these drilling and production problems due to concentration and size effect of the materials along with the restricted functional ability of macro and micro particles. However, due to ultra fine particle sizes, very low concentration requirement, unrestricted with special functional groups, nanos can exercise their full functional role in preventing these problems in the first place then to control them in the second place.” Nanotechnology and nanomaterials have huge potential to overcome future drilling challenges.

2.4 Mud Weight

Mud weight is one of the important drilling fluid properties in drilling mud because it contributes to control and balance formation pressure and wellbore stability. Formulation of mud is necessary to achieve desire mud weight. Formulation of mud weight can be done by using general material balance equation.

Material Balance Equations [8]

Material balance equations are used for calculating volumes and densities when two or more insoluble materials are mixed together.

The material balance equation is:

V1W1 + V2W2..... = VFWF ………………………………...…………………. 2.1

V1 + V2..... = VF...…………………….. 2.2

Where:

V1 = Volume of first material to be mixed together

W1 = Density of first material

V2 = Volume of second material to be mixed together

W2 = Density of second material

VF = Total or sum of all volumes mixed together

WF = Density of total mixture. Proportional average of all volumes mixed together

2.5 Rheology

Rheology is defined as physics of the flow and the deformation of matter. Rheology and the associated annular hydraulics relate directly to borehole stability and how effectively the borehole is cleaned.[9]

2.5.1 Shear Stress [9]

An applied force (F), acting over an area (A), causes the layers to slide past one another. However, there is a resistance, or frictional drag, force that opposes the movement of these plates. This resistance or drag force is called shear stress (τ). In equation form,

$$\tau = \frac{F}{A} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 2.3$$

With shear stress having typical units of lb/100 ft^2.

2.5.2 Shear Rate [9]

The difference in the velocities between two layers of fluid divided by the distance between the two layers is called the shear rate (γ). In equation form,

$$\gamma = \frac{Velocity\ \ Different}{Distance} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 2.4$$

With typical units of $\frac{ft/sec}{ft} = \frac{1}{sec} = sec^{-1}$ or, reciprocal seconds.

2.5.3 Newtonian Fluid Model [9]

The Newtonian Fluid Model is the basis from which other fluid models are developed. The flow behavior of Newtonian fluids has been discussed and it can be seen from this equation that the shear stress-shear rate relationship is given by:

$$\tau = (\mu)(\gamma) \; \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 2.5$$

Where,

τ = shear stress

μ = viscosity

γ = shear rate

At a constant temperature, the shear stress and shear rate are directly proportional. The proportionality constant is the viscosity (μ).

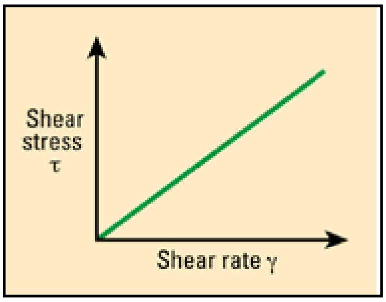

Figure 3: Flow Curve for a Newtonian Fluid [9]

2.5.4 Bingham Plastic Model [9]

The shear stress / shear rate relationship for the Bingham Plastic Model is given by:

$$\tau = \tau_{\circ} + (\mu_{\infty})(\gamma) \quad \text{.....................................} \; 2.6$$

Where,

τ = shear stress

$\tau_{\circ}$ = yield point

μ_{∞} = Plastic viscosity

γ = shear rate.

The flow curve for a Bingham Plastic fluid is illustrated in Figure 4. The effective viscosity, defined as the shear stress divided by the shear rate, varies with shear rate in the Bingham Plastic Model. The effective viscosity is visually represented by the slope of a line from the origin to the shear stress at some particular shear rate. The slopes of the dashed lines represent effective viscosity at various shear rates. As can be seen, the effective viscosity decreases with increased shear rate. As discussed in the Viscosity section, this is referred to as shear thinning.

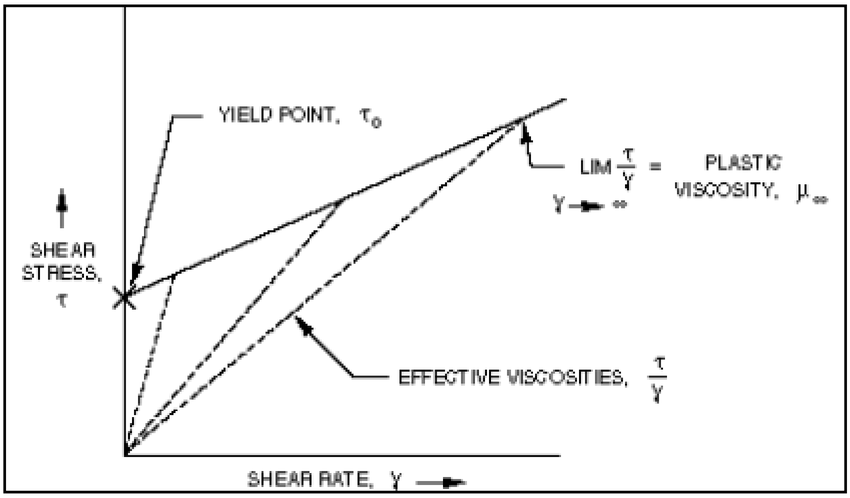

Figure 4: Flow Curve for a Bingham Plastic Fluid [9]

As shear rates approach infinity, the effective viscosity reaches a limit called the Plastic Viscosity. The plastic viscosity of a Bingham Plastic fluid represents the lowest possible value that the effective viscosity can have at an infinitely high shear rate, or simply the slope of the Bingham Plastic line.

The Bingham Plastic Model and the terms plastic viscosity (PV) and yield point (YP) are used extensively in the drilling fluids industry. Plastic viscosity is used as an indicator of the size, shape, distribution and quantity of solids, and the viscosity of the liquid phase. The yield point is a measure of electrical attractive forces in the drilling fluid under flowing conditions.

- PV should be as low as possible for fast drilling and is best achieved by minimizing colloidal solids.
- YP must be high enough to carry cuttings out of the hole, but not so large as to create excessive pump pressure when starting mud f low.

2.5.5 Power Law Model [16]

Another model that can describe non-Newtonian fluid is Power Law Model. The shear rate and shear stress curve has the exponential equation. A fluid described by the two parameter rheological model of a pseudo plastic fluid, or a fluid whose viscosity decreases as shear rate increases.

$$\tau = K\ x\ (\gamma)^n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.7$$

In this equation, K is the consistency index and n is the f low behavior index. The value of n is less than unity for Power Law.

Example: Water-base polymer muds, especially those made with XC polymer

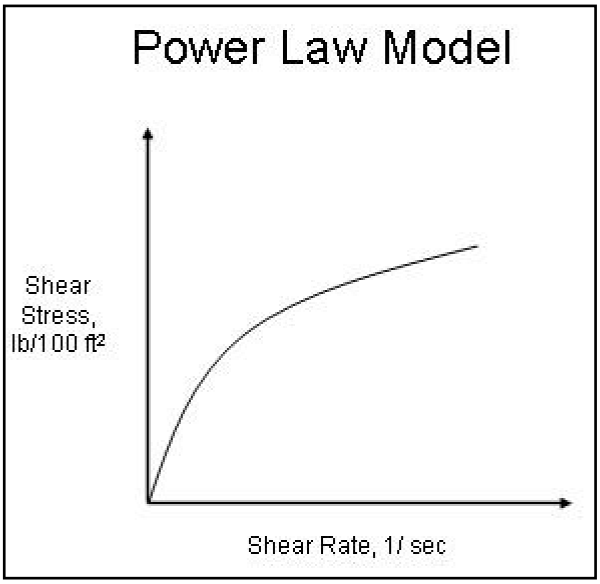

Figure 5: Power Law fluid model[27]

2.5.6 Plastic Viscosity [23]

Plastic viscosity is the resistance of fluid to flow. Any increase in solid content in drilling mud as Barite, drill solid, lost circulation material, etc will result in higher the plastic viscosity. Plastic viscosity will decrease with increasing temperature while drilling because viscosity of the base fluid decreases.

Using Fann35 Viscometer, the plastic viscosity for the mud is measured by this equation:

Plastic Viscosity (PV) = Reading at 600 rpm – Reading at 300 rpm…………….. 2.8

2.5.7 Yield Point [24]

Yield Point (YP) is resistance of initial flow of fluid or the stress required in order to move the fluid. Yield Point (YP) is the attractive force among colloidal particles in drilling mud and indicates the ability of the drilling mud to carry cuttings to surface. Frictional pressure loss is directly related to the YP. Higher YP will have high pressure loss while the drilling mud is being circulated.

Yield Point (YP) = Reading at 300 rpm – Plastic Viscosity (PV) ………………2.9

2.5.8 Gel Strength [25]

Gel strength is the shear stress of drilling mud that is measured at low shear rate after the drilling mud is static for a certain period of time. The gel strength is one of the important drilling fluid properties because it demonstrates the ability of the drilling mud to suspend drill solid and weighting material when circulation is ceased. Evaluation of gel strength consists of two types according to API standard which are 10 second and 10 minute reading.

"Gel strengths occur in drilling fluids due to the presence of electrically charged molecules and clay particles which aggregate into a firm matrix when circulation is stopped. Two types of gel strength occur in drilling fluids, progressive and fragile. A progressive gel strength increases substantially with time. This type of gel strength requires increased pressure to break circulation after shutdown. A fragile gel strength increases only slightly with time, but may be higher initially than a progressive gel." [9]

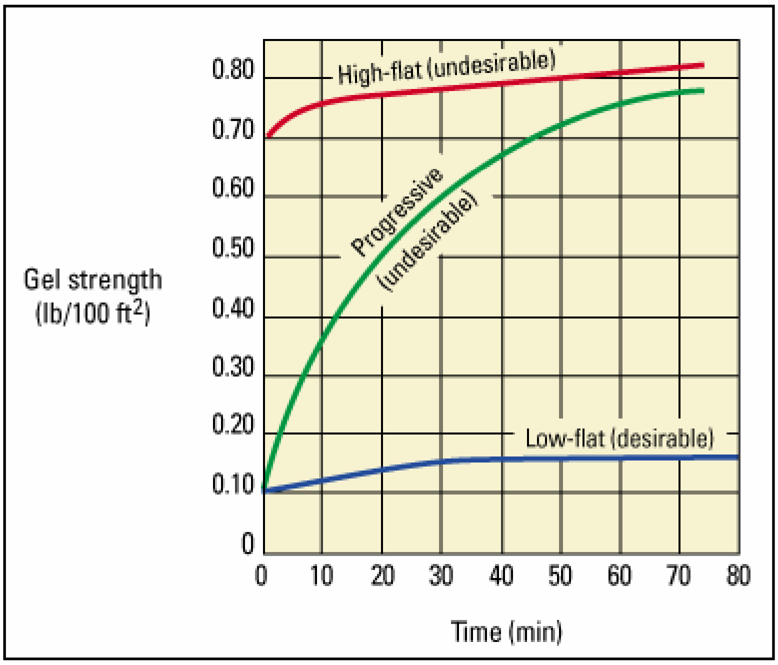

Figure 6: Gel Strength Characteristics vs. Time [9]

- Gel 10 minutes – the reading of maximum deflection at 3 rpm speed using Fann 35 Viscometer after the mud is let in static condition for10 minutes.
- Gel 10 seconds – the reading of maximum deflection at 3 rpm speed using Fann 35 Viscometer after the mud is let in static condition for10 seconds.

2.6 Electric Stability [8]

The electrical stability (ES) of an oil-based drilling fluid is the stability of the emulsions of water in oil, or the amount of current required to break the emulsifier down and allow the saline water to coalesce.

1. An electrical probe is inserted into the drilling fluid and the voltage increased until the emulsion breaks down
    a. the measure of emulsion breakdown is indicated by current flow
    b. relative stability is recorded as the amount of voltage at the breakdown point
2. E.S. is recorded as the voltage reading and temperature of the drilling fluid sample
    a. adding emulsifier will raise the E.S. readings
    b. normal “fresh” mud is about 300 or higher
    c. during drilling, the E.S. can increase to 800 or higher

2.7 Filtration [9]

There are two types of filtration which are static and dynamic. Static filtration defines as the fluid is in static condition or not moving in the hole. Dynamic filtration defines as the fluid in the hole is moving or circulates.

Dynamic filtration differs from static filtration in that drilling fluid velocity tends to erode the wall cake even as it is being deposited on permeable formations. As the rate of erosion equals the rate of build up of the wall cake, equilibrium is established. In static filtration, the wall cake will continue to be deposited on the borehole.

2.8 Filter Cake [9]

The permeability of the filter cake is one of the most important factors in controlling filtration. The size, shape, and concentration of the solids which constitute the filter cake determine the permeability. If the filter cake is composed primarily of coarse particles, the pores will be larger, therefore, the filtration rate greater. For this reason, bentonite with its small irregular shaped platelets forms a cake of low permeability. Bentonite platelets as well as many polymers compact under pressure to lower permeability, hence the term, cake compressibility.

CHAPTER 3

METHODOLOGY

3.1 Project Planning

Table 2: Project Planning

1. Preparation of oil based mud in laboratory (Sarapar 147)
2. Lab experiment: Measure the rheology of 2 mud samples; 1) mud with silica nanoparticle 2) mud without silica nanoparticle
3. Lab experiment: Put both mud samples into hot roller oven for 16 hours (to achieve reservoir condition)
4. Lab experiment: Measure the fluid loss of both samples (HPHT Fluid Loss)
5. Lab experiment: Measure the rheology of 2 mud samples after ageing; 1) mud with silica nanoparticle 2) mud without silica nanoparticle
6. Compare the result obtained
7. Analyze and interpret the results

3.2 Flowchart Process

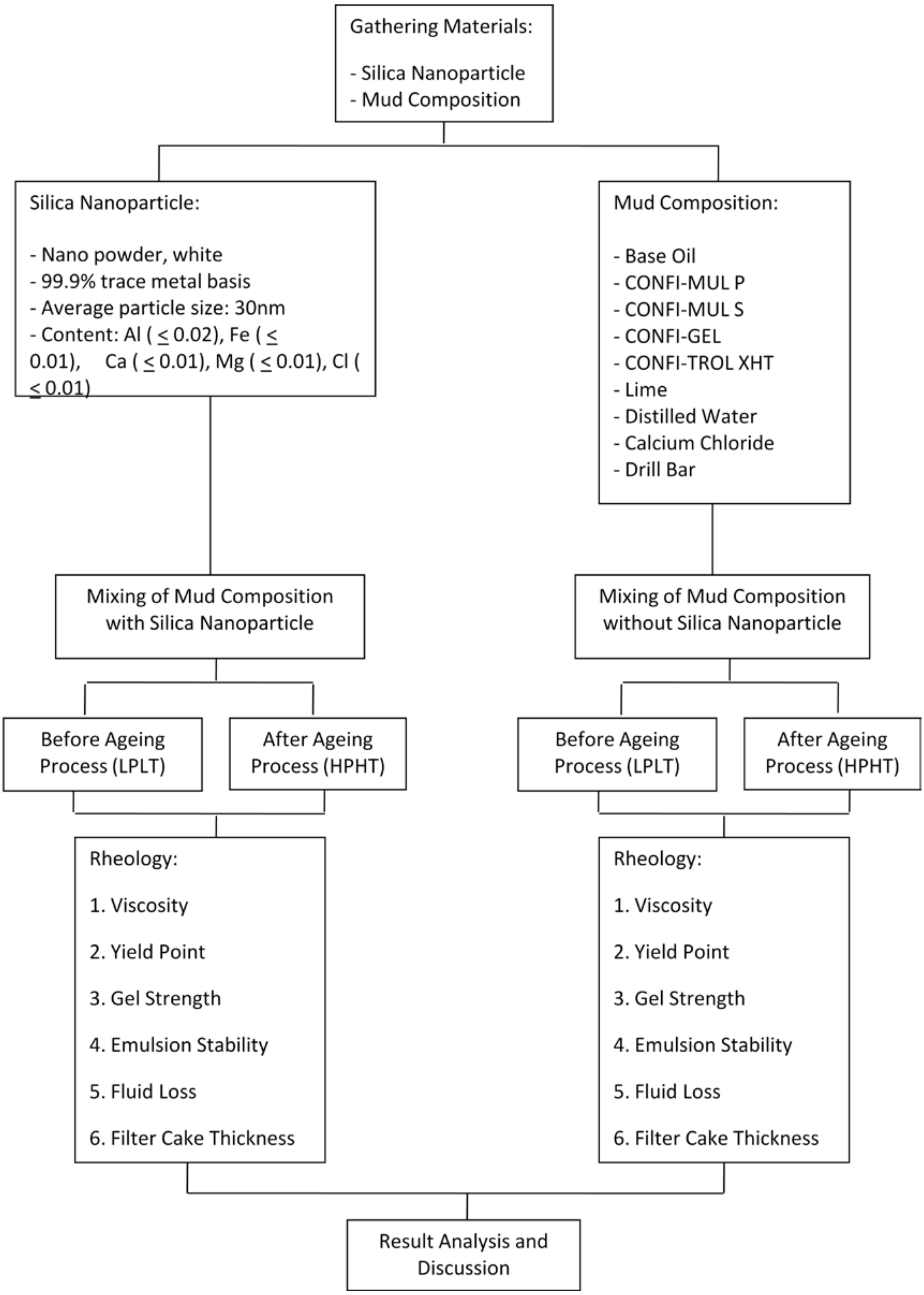

Figure 7: Flowchart process

3.3 Mixing Procedure

Table 3: Mixing procedure for OBM preparation

Product	Order	Mixing time, min
Sarapar 147 oil	1	0
CONFI MUL P	2	5
CONFI MUL S	3	5
CONFI GEL	4	5
CONFI TROL XHT	5	5
Lime	6	5
Brine (Calcium Chloride + Distilled Water)	7	5
Silica Nanoparticle (For OBM with Silica Nanoparticle only)	8	5

3.4 Oil Based Mud Preparation

- Addition of oil based mud components must in their sequence to optimize the performance of each component.

1. Add the required quantity of base oil to the mixing vessel
2. Add the primary and secondary emulsifier as required.
3. Add the organoclay gallant as required.
4. Add filtration control additives
5. Add lime in excess.
6. Add require amount of brine.
7. Add silica nanoparticle 1% material. (this step only for OBM with silica nanoparticle additive)
8. Mix for a long time to ensure good emulsion is formed.
9. Add weighting agent material as required for the desire density

Table 4: Constant Elements in OBM Formulation

Product	Description	Quantity (gram)
CONFI-MULP	Primary emulsifier	3.00
CONFI-MULS	Secondary emulsifier	9.00
CONFI-GEL	Viscosifiers	8.50
CONFI-TROLXHT	Fluid loss control	8.00
LIME	Alkalinity source	8.00

Formulation for Sarapar 147 and Sarapar 147 + Silica Nanoparticle samples as below:

Table 5: Formulation for Sarapar 147 mud sample

Products	Quantity (g)
Base oil (Sarapar 147)	159.98
CONFI-MULP	3.00
CONFI-MULS	9.00
CONFI-GEL	8.50
CONFI-TROLXHT	8.00
LIME	8.00
Distilled Water	67.39
CaCl2	26.31
DRILL-BAR	192.78
Silica Nanoparticle	0.00

Table 6: Formulation for Sarapar 147 + Silica Nanoparticle mud sample

Products	Quantity (g)
Base oil (Sarapar 147)	157.32
CONFI-MULP	3.00
CONFI-MULS	9.00
CONFI-GEL	8.50
CONFI-TROLXHT	8.00
LIME	8.00
Distilled Water	67.28
CaCl2	26.90
DRILL-BAR	195.26
Silica Nanoparticle	4.61

3.5 Rheology Test

3.5.1 Mud Viscosity Test

Procedure:

1. Place a recently agitated sample in the cup, tilt back the upper housing of the viscometer, locate the cup under the sleeve (the pins on the bottom of the cup fit into the holes in the base plate), and lower the upper housing to its normal position.
2. Turn the knurled knob between the rear support posts to raise or lower the rotor sleeve until it is immersed in the sample to the scribed line.
3. Stir the sample for about 5 seconds at 600 RPM, and then select the RPM desired for the best.
4. Wait for the dial reading to stabilize.
5. Record the dial reading and RPM.

3.5.2 Gel Strength Test

Procedure:

1. Stir a sample at 600 RPM for about 15 seconds.
2. Turn the RPM knob to the STOP position
3. Wait the desired rest time (normally 10 seconds or 10 minutes).
4. Switch the RPM knob to the GEL position.
5. Record the maximum deflection of the dial before the Gel breaks, as the Gel strength in lb/100 ft^2.

3.5.3 Yield Strength Test

Procedure:

By means of the viscometer calculations procedure, determine the Apparent and Plastic Viscosities, Yield Point and initial 10 seconds and final 10 minutes Gel Strength parameters.

Yield Point (YP) = 300 RPM – Plastic Viscosity.

3.5.4 Emulsion Stability Test

Procedure:

1. Before placing the probe in the mud, it is essential to test the meter in air.
2. The reading should go off scale and the display start flashing. If the meter does not go off scale, it is an indication that the probe is shorting out due to an accumulation of detritus between the two prongs. It is clear that the probe can short out before the end point of the mud is reached and an erroneous reading will result. The probe should be carefully cleaned and retested in air to ensure that it now goes off scale before testing the mud.
3. Place the clean and checked probe in the sample at 120˚ F and use it to stir the fluid to ensure homogeneity. Position the probe so it does not touch the bottom or sides of the heated cup, ensuring the tip of the electrode is completely immersed.
4. Press the button to initiate the voltage ramp, holding the probe still until the end point is reached and a steady reading is seen in the digital display. Note the reading.
5. Repeat the test. The two ES values should be within 5% and anything greater would indicate a problem with the equipment.
6. The result is the average of the two readings.

3.5.6 HPHT Fluid Loss Test

Procedure:

1. Turn on heated jacket at the mains and insert a thermometer into the jacket and leave to preheat to the desired temperature.
2. Check out all the “O” rings on the HPHT bomb and lid.
3. With stem valve closed on bottom of cell, fill up cell with mud to within 0.5”of the „O‟ ring groove, to allow for thermal expansion.
4. Insert filter paper into the cell followed by the bottom cell plate assembly over the filter paper and twist to align with the safety locking lugs. Ensure the lid stem is open while doing this to avoid damaging the filter paper.
5. Tighten the 6 grub screws evenly using the Allan key provided.
6. Ensure all stem valves are tightly closed.
7. Invert cell and place in filtration mounted heated jacket assembly. Rotate the bomb until it seats on the locking pin. Insert a thermometer into the HTHP cell.

8. Place a CO or N cartridge in each regulator and tighten up the retainers.
9. Place the pressure unit on top valve and lock into place using a locking pin. Lock the bottom pressure unit to the bottom valve into place, again ensuring that locking pin is inserted.
10. Apply 100 psi to both ends of the HTHP cell with the valves still closed.
11. Open the top valve by turning 1/4 to 1/2 anticlockwise to apply 100 psi to the mud while heating to prevent the mud from boiling prior to reaching the target temperature. The time for heating the mud sample to the target temperature should not exceed 60 minutes.
12. When the cell reaches the required test temperature open the bottom stem (1/2 turn) and then increase the pressure on the top regulator to 600 psi over +/- 20 seconds.
13. Commence the test. The test should be carried out as soon as the bomb reaches the test temperature.
14. If the pressure on the bottom regulator increases significantly above 100 psi bleed off some of the filtrate into the graduated cylinder.
15. Collect the filtrate for 30 minutes maintaining the temperature to within ± 5˚F.
16. Once the test has finished close the top and bottom valves and shut off the pressure supply from the regulators. Bleed the lines using the relief valves provided.
17. Allow filtrate to cool for 30 minutes and then draw off into a graduated 20 ml measuring cylinder and read volume. SAVE the filtrate for ionic analysis.
18. CAUTION - the cell still contains 500 psi pressure, so cool cell to room temperature ideally in a water bath or alternative safe place and then bleeds off the pressure slowly by opening the valves.
19. Disassemble the cell and discard mud into mud waste container only. Save filter paper handling with care and wash filter cake with a gentle stream of distilled water.
20. Measure and report the thickness of the cake to the nearest 1/32” (0.8 mm).

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Before Ageing Properties:

Table 7: Before ageing process

Properties	Spec	Sarapar 147	Sarapar 147 + Silica Nanoparticle
Mud density, lb/gal		11.1	11.4
Rheological Properties			
600 rpm		106.5	125.0
300 rpm		66.0	77.5
200 rpm		53.0	61.0
100 rpm		39.5	42.0
6 rpm	8-16	18.5	19.0
3 rpm		17.0	17.0
PV, cp	<35	40.5	47.5
YP, lb/100 ft^2	15-25	25.5	30
Gel 10 sec, lb/100 ft^2	8-18	20	21
Gel 10 min, lb/100 ft^2	15-30	29	29
Electric Stability, Volts @ 120°F	>400	420	475
Apparent Viscosity, cp		53.25	62.5

4.2 After Ageing Properties:

Table 8: After ageing process

Properties	Spec	Sarapar 147	Sarapar 147 + Silica Nanoparticle
Mud density, lb/gal		11.0	11.3
Rheological Properties			
600 rpm		89.0	145.0
300 rpm		52.0	95.0
200 rpm		37.0	72.0
100 rpm		22.0	45.0
6 rpm	8-16	4.0	10.0
3 rpm		3.0	7.0
PV, cp	<35	38.0	50.0
YP, lb/100 ft^2	15-25	14.0	45.0
Gel 10 sec, lb/100 ft^2	8-18	7.0	12.0
Gel 10 min, lb/100 ft^2	15-30	10.0	22.0
HPHT Fluid Loss, ml/30 min @ 275°F / 500 psi	<4	4.8	2.4
Filter Cake thickness, mm	<2	3.71	4.29
Electric Stability, Volts @ 120°F	>400	329	433
Apparent Viscosity, cp		44.5	72.5

4.3 Result Analysis

To compare mud properties of OBM with and without silica nanoparticle, Sarapar 147 and Sarapar 147 with silica nanoparticle were tested. The relationships of each mud properties before and after hot rolling process are shown in the following figures.

The main focus for mud rheology is 6 rpm reading because the initial gel strength will be more or less the same as the 6 rpm reading which mud programs will specify a range for the 6 rpm reading. It is a good indicator of a colloidal solids build up that may not be detected by solid analysis.

Table 9: Viscosity at 6 rpm before and after ageing process

Viscosity at 6 rpm	Sarapar 147	Sarapar 147 + Silica Nanoparticle
Before Ageing	18.5	19.0
After Ageing @ 275 °F / 16 hr	4.0	10.0

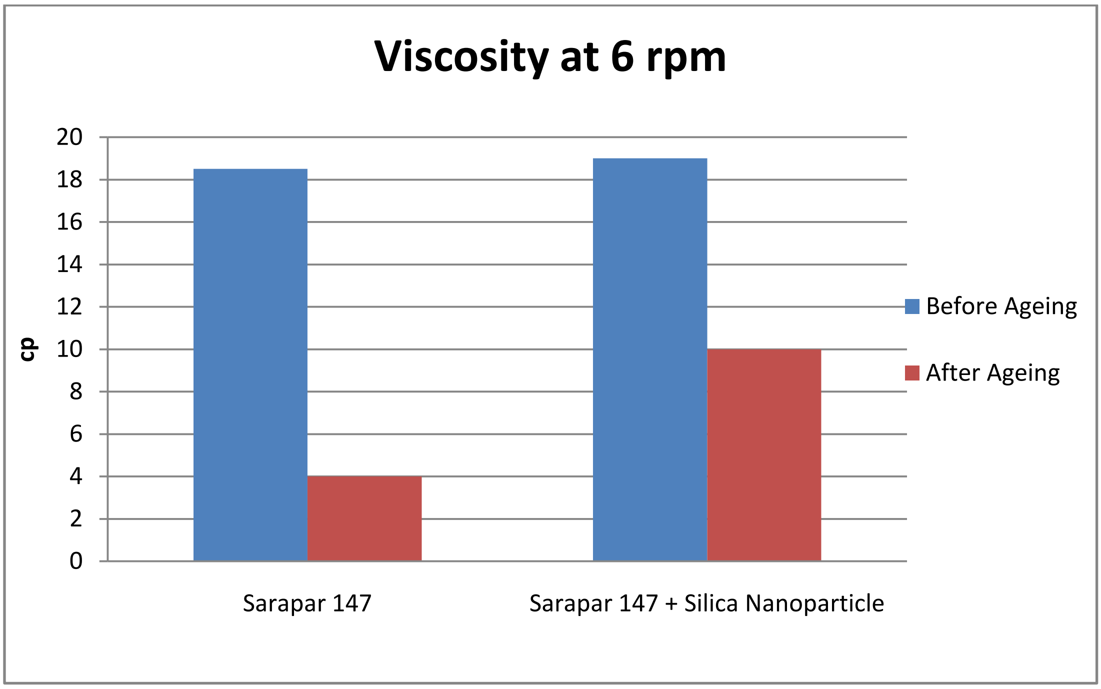

Figure 8: Viscosity at 6 rpm

Specific value of rheology reading at 6 rpm of this study is 8-16cp which Sarapar 147 and Sarapar 147 + Silica Nanoparticle seems to give satisfy value before ageing process. After ageing process, Sarapar 147 give 4 cp value which is below the standard specification compare to 10 cp value generate by Sarapar 147 + Silica Nanoparticle. Different performance produce from these two mud sample, Sarapar 147 + Silica Nanoparticle is most preferable than Sarapar 147.

Plastic Viscosity (PV) is the resistance of fluid to flow. Plastic viscosity is influence by the solid content in drilling mud. Increase of solid content will result higher plastic viscosity while low solid content will result in low plastic viscosity indicates that the mud is capable to drill rapidly. In this experiment, CONFI-MUL P and CONFI-MUL S will act as primary and secondary emulsifier and increase the plastic viscosity of both muds.

Table 10: Comparison of plastic viscosity

Plastic Viscosity (PV)	Sarapar 147	Sarapar 147 + Silica Nanoparticle
Before Ageing	40.5	47.5
After Ageing @ 275 °F / 16 hr	38.0	50.0

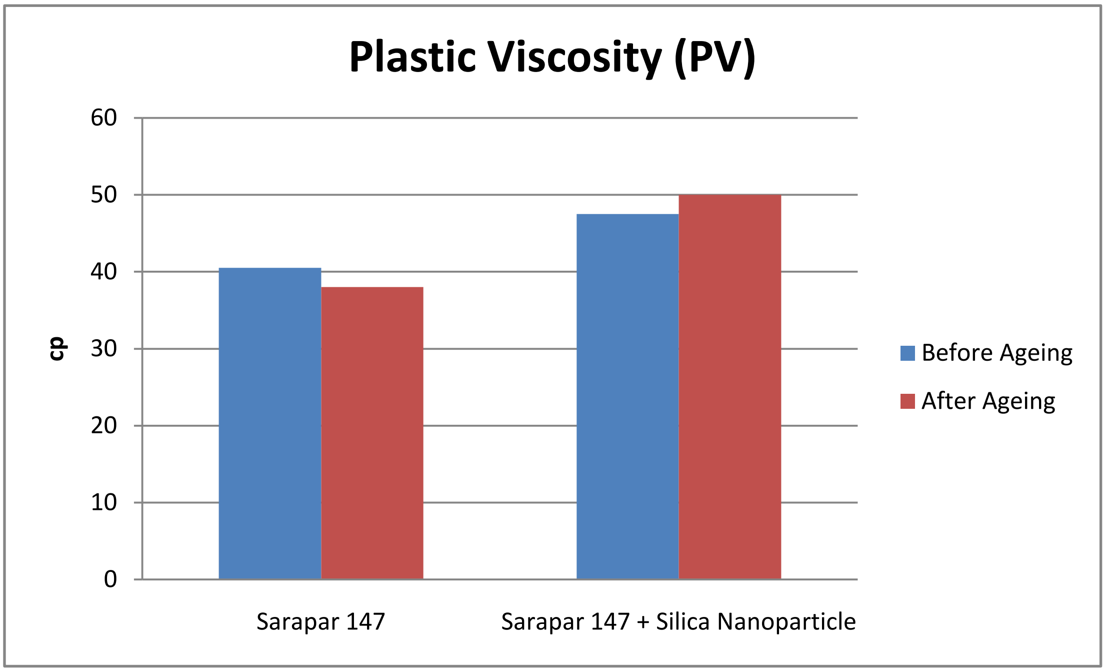

Figure 9: Plastic viscosity bar chart for Sarapar 147 and Sarapar 147 + Silica Nanoparticle

From the results of PV above from Sarapar 147 and Sarapar 147 + Silica Nanoparticle, it shows that Sarapar 147 have the lowest plastic viscosity before and after ageing process compare to Sarapar 147 + Silica Nanoparticle. Specific range value of PV in this study is lower than 35 cp. Sarapar 147 and Sarapar 147 + Silica Nanoparticle give higher values before and after ageing process compare to specific range. Although the value of PV for both mud a greater than specific range, it shows that Sarapar 147 have the lowest plastic viscosity before and after ageing process compare to Sarapar 147 + Silica Nanoparticle. Comparing the performance between these two mud samples, Sarapar 147 have good plastic viscosity than Sarapar 147 + Silica Nanoparticle.

Yield Point (YP) is resistance of initial flow of fluid or the stress required in order to move the fluid. YP is used to evaluate the ability of a mud to lift cutting out of the annulus measured in unit of lb/100 ft^2. It is also indicate how much pressure needed for the pump to start circulate cutting from wellbore to the surface. Very high YP can cause high pressure loss while the drilling mud is being circulated.

Table 11: Comparison of yield point

Yield Point (YP)	Sarapar 147	Sarapar 147 + Silica Nanoparticle
Before Ageing	25.5	30.0
After Ageing @ 275 °F / 16 hr	14.0	45.0

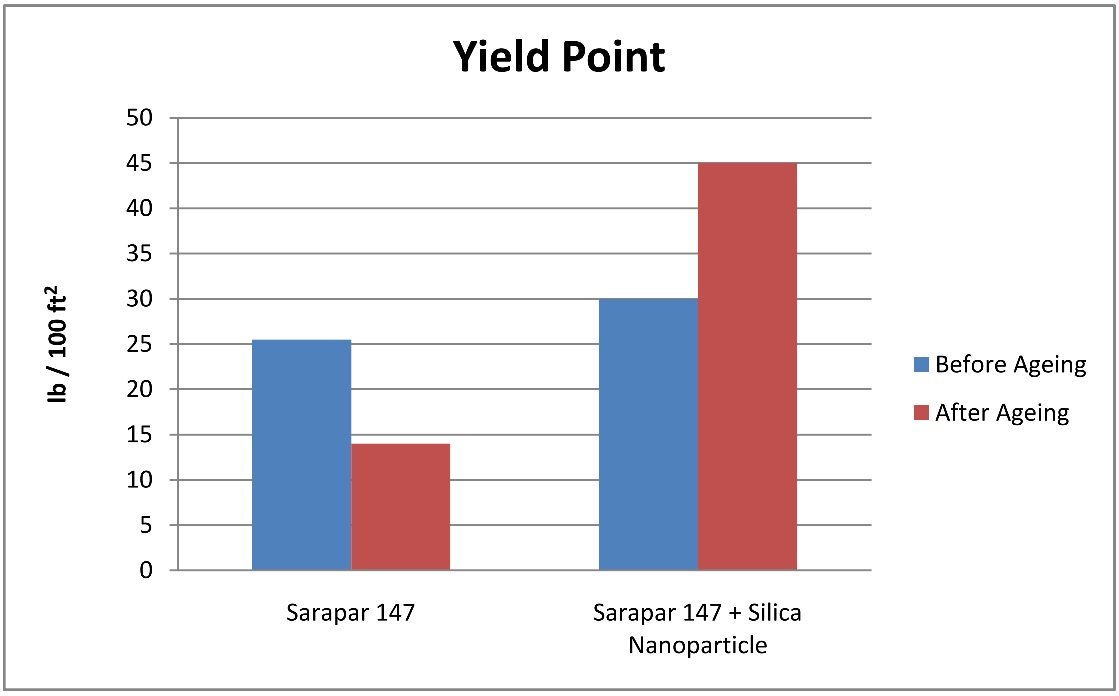

Figure 10: Yield point bar chart for Sarapar 147 and Sarapar 147 + Silica Nanoparticle

In this study, the specific range for yield is 15-20 cp for before ageing and 15-25 cp after ageing process. Sarapar 147 give the satisfy value for before and after ageing process than Sarapar 147 + Silica Nanoparticle mud sample which have very high YP before and after ageing process. Thus, Sarapar 147 + Silica Nanoparticle seems to have more drill solid compare to Sarapar 147. For HPHT condition, yield point of Sarapar 147 has better yield point property compare to Sarapar 147 + Silica Nanoparticle but it is still not good enough to conclude that Sarapar 147 base mud is a suitable drilling fluid because it is not in the range of yield point specification.

Gel strength is the shear stress of drilling mud that is measured at low shear rate after the drilling mud is static for a certain period of time. It is important properties in drilling fluid to represent the ability of the drilling mud to suspend drill solid and weighting material when circulation is ceased. There are two reading of gel strength; 10 second and 10 minute according to API Recommended Practice 13B-1 with speed of 3 rpm. If the mud has the high gel strength, it will create high pump pressure in order to break circulation after the mud is static for long time.

Table 12: Comparison of gel strength for 10 second

Gel Strength for 10 second	Sarapar 147	Sarapar 147 + Silica Nanoparticle
Before Ageing	20.0	21.0
After Ageing @ 275 °F / 16 hr	7.0	12.0

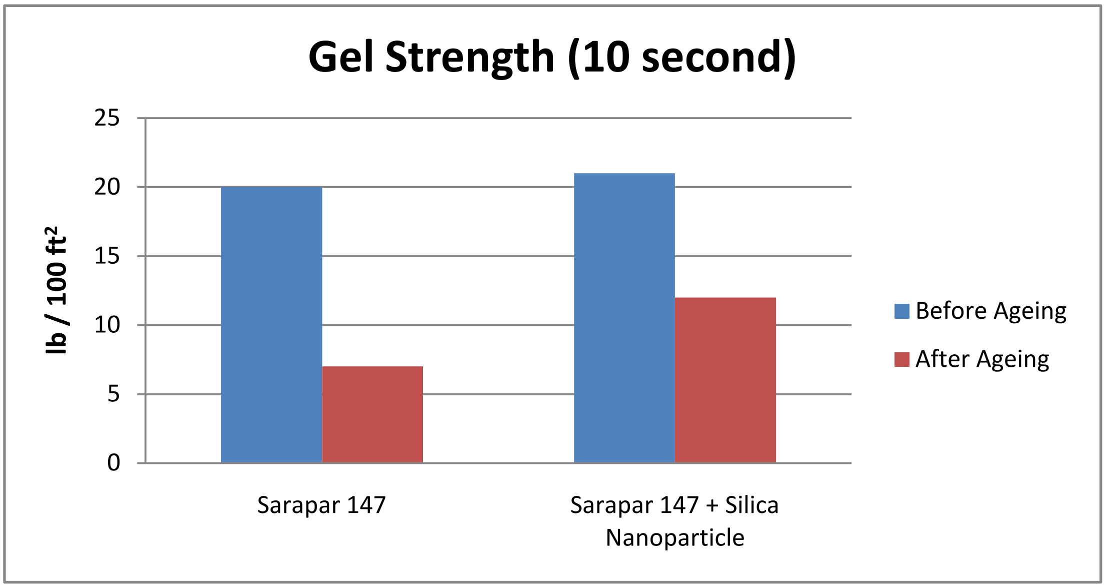

Figure 11: Gel strength (10 second) bar chart for Sarapar 147 and Sarapar 147 + Silica Nanoparticle

Table 13: Comparison of gel strength for 10 minute

Gel Strength for 10 minute	Sarapar 147	Sarapar 147 + Silica Nanoparticle
Before Ageing	29.0	29.0
After Ageing @ 275 °F / 16 hr	10.0	22.0

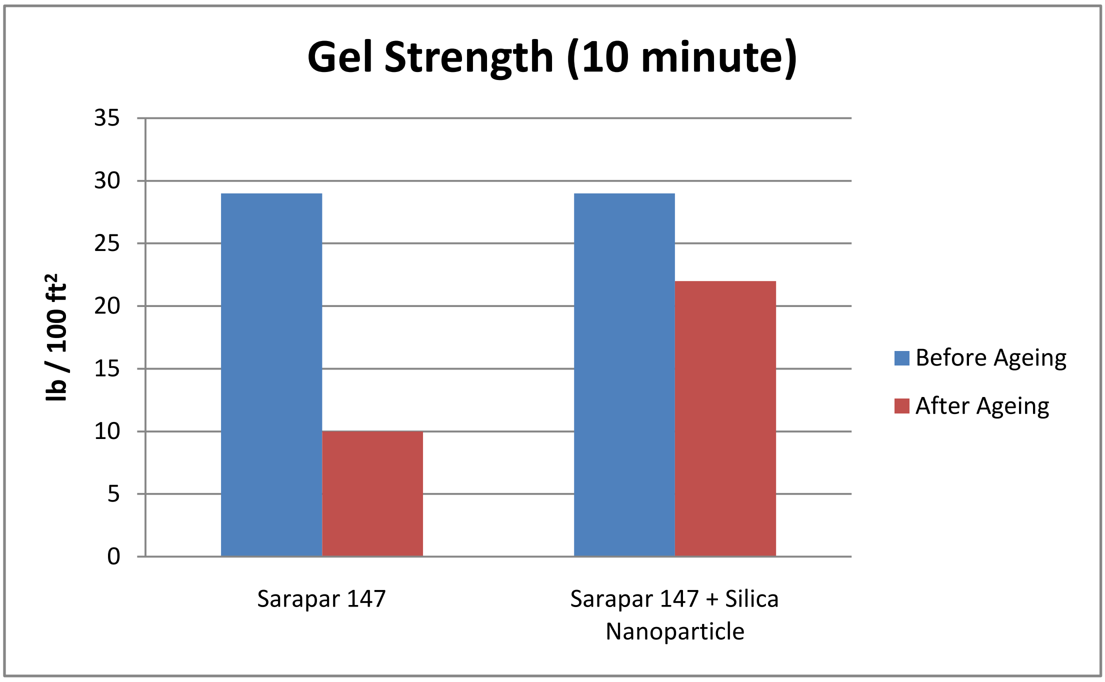

Figure 12: Gel strength (10 minute) bar chart for Sarapar 147 and Sarapar 147 + Silica Nanoparticle

Specific range of gel strength before and after ageing process for 10 second is 8-18 lb/100ft^2 and 10 minute is 15-30 lb/100ft^2. The sample of Sarapar 147 + Silica Nanoparticle gives a better value compare to Sarapar 147 sample. Sarapar 147 + Silica Nanoparticle seems to be more satisfied because it initial and after ageing result shows consistent value (inside the range).

Emulsion stability test is one of the important properties in oil and synthetic based mud. Emulsion stability shows the voltage of current to flow in the mud and represent mud stability. The API standard for good emulsion of oil based mud is above 400 volts. The higher values of emulsion stability indicate the mud has good emulsion and vice versa.

Table 14: Comparison of emulsion stability

Emulsion Stability	Sarapar 147	Sarapar 147 + Silica Nanoparticle
Before Ageing	420	475
After Ageing @ 275 °F / 16 hr	329	433

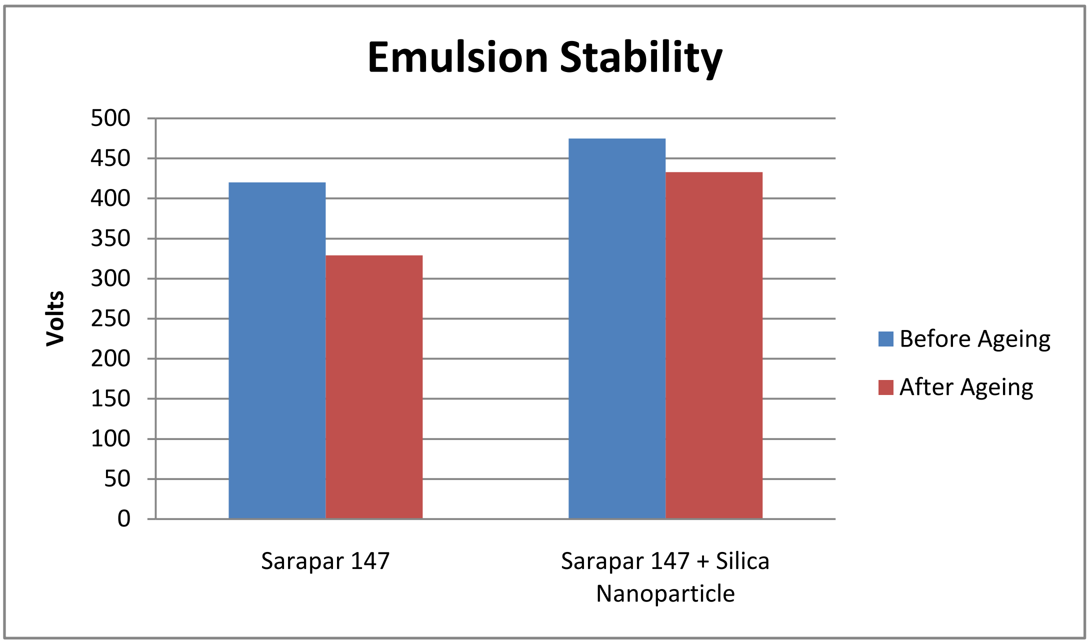

Figure 13: Emulsion stability bar chart for Sarapar 147 and Sarapar 147 + Silica Nanoparticle

Initially, Sarapar 147 and Sarapar 147 + Silica Nanoparticle have higher emulsion stability value than API standard which indicate both mud samples have good emulsion. After ageing process, Sarapar 147 + Silica Nanoparticle shows a consistence value compare to Sarapar 147. Sarapar 147 + Silica Nanoparticle give satisfy reading as it exceeds the API standard value of emulsion stability for oil based mud before and after ageing process. This proved that silica nanoparticle can improve the emulsion stability for oil based mud.

High pressure high temperature (HPHT) fluid loss test is created in order to simulate the downhole condition. Fluid loss is defined as the amount of water expelled from the drilling mud under particular pressure and temperature after 30 minute. The fluid loss gives an indicator of the fluids interaction with the bore hole under simulated conditions. Low value of filtrate loss is more preferred which cause minimum swelling of clays and minimum formation damage.

Table 15: Comparison of HPHT fluid loss

HPHT Fluid Loss (ml)	Sarapar 147	Sarapar 147 + Silica Nanoparticle
After Ageing @ 275 °F / 16 hr	4.8	2.4

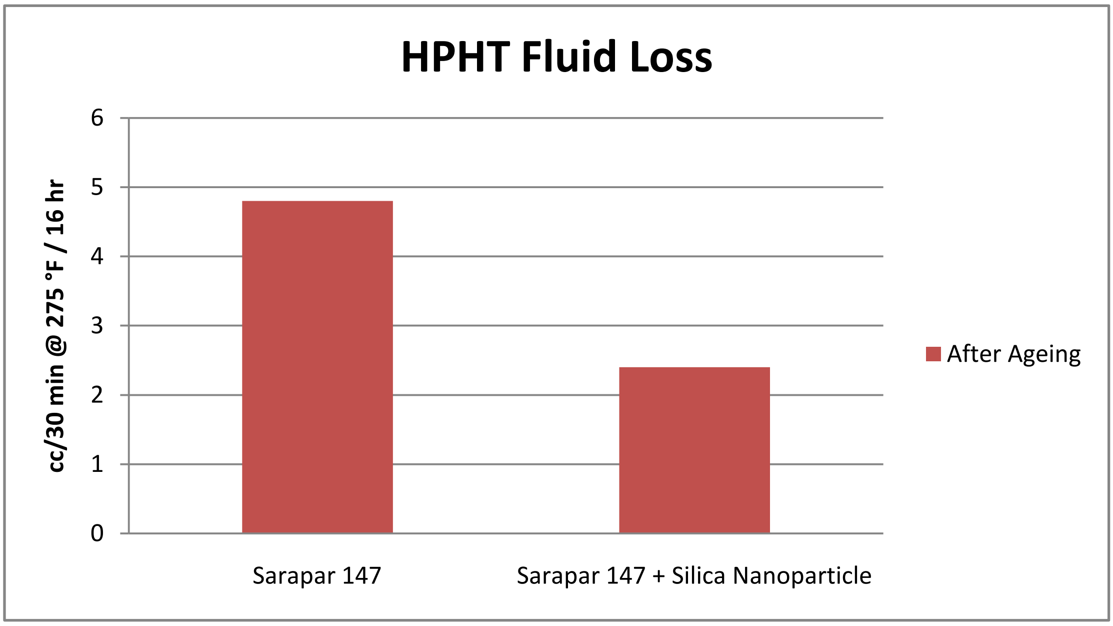

Figure 14: HPHT fluid loss bar chart for Sarapar 147 and Sarapar 147 + Silica Nanoparticle

Mud sample with minimum fluid loss is considered as a good mud. Sarapar 147 and Sarapar 147 + Silica Nanoparticle result in different fluid loss which are 4.8ml and 2.4ml. The standard value of fluid loss in this project is set up below than 4ml. Since Sarapar 147 + Silica Nanoparticle has lesser fluid loss compare to Sarapar 147, it seems have a good fluid loss property and capable to minimum filtration loss and formation damage in borehole.

Filter cake is a layer formed by solid particles in drilling mud against porous zones due to differential pressure between hydrostatic pressure and formation pressure and it is always occurred while drilling the wells. Practically, the filter cake should be less than 2mm at the bottom hole temperature of 275 °F. Thin and impermeable layer of filter cake should form on the wall to prevent fluid entering the rock and reacting with the wellbore formation.

Table 16: Comparison of filter cake thickness

Filter Cake Thickness (mm)	Sarapar 147	Sarapar 147 + Silica Nanoparticle
After Ageing @ 275 °F / 16 hr	3.71	4.29

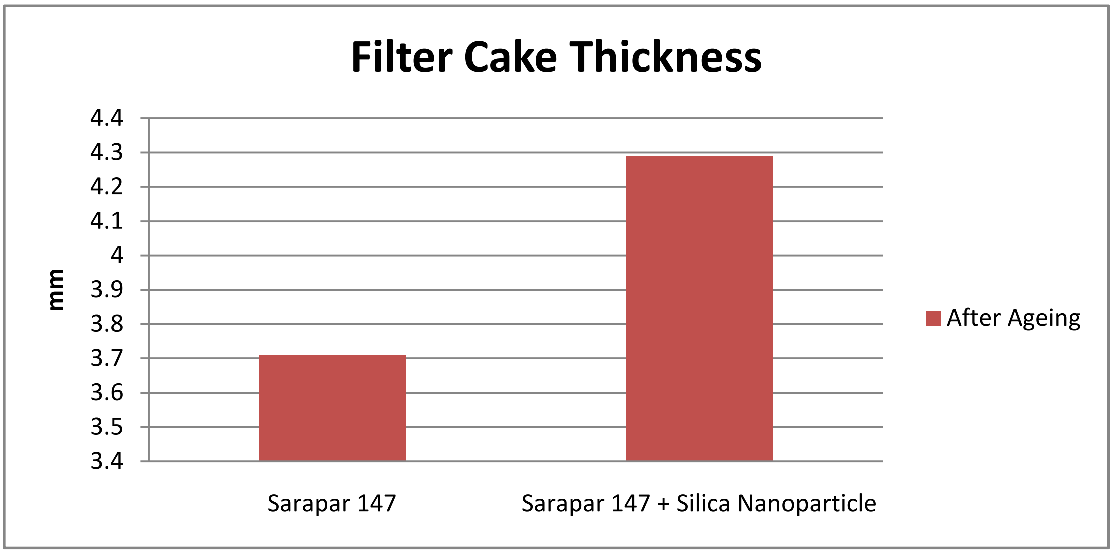

Figure 15: Filter cake thickness bar chart for Sarapar 147 and Sarapar 147 + Silica Nanoparticle

Filter cake thickness of Sarapar 147 has lower value than Sarapar 147 + Silica Nanoparticle. Although, Sarapar 147 has low value of filter cake, the standard specification of filter cake set up in this project is < 2mm. Both mud samples have bad filter cake thickness which is not suitable to use under HPHT condition.

4.4 Discussion

From the above comparison, Sarapar 147 + Silica Nanoparticle give more preferred overall properties of drilling fluid compare to Sarapar 147 mud sample. Sarapar 147 + Silica Nanoparticle mud sample shown better properties after ageing process compare to Sarapar 147. For 6 rpm viscosity, gel strength (10 second and 10 minute), HPHT fluid loss and emulsion stability test, Sarapar 147 + Silica Nanoparticle generate better result than Sarapar 147. The most significant result from this experiment is the HPHT fluid loss of Sarapar 147 + Silica Nanoparticle which has low fluid loss compare to Sarapar 147. This shown silica nanoparticle have ability to become fluid loss additive for drilling mud.

Rheology and HPHT fluid loss have significant effect in drilling mud. In any drilling mud formulation, mud rheology need to meet requirement of industry standard specification that being used in oil and gas industry. In accordance this specification, if mud formulation meets the range of these specifications, it will be considered as good mud and ready to be used in real time applications.

Table 17: Standard specification after ageing process

Mud Properties	Specification
Mud Density, ppg	10-12
6 rpm dial reading	8-16
Plastic Viscosity (PV), cp	<35
Yield Point (YP), $lb/100ft^2$	15-35
10 sec gel strength, $lb/100ft^2$	8-18
10 min gel strength, $lb/100ft^2$	15-30
HTHP Fluid Loss @ 275 °F , 500 psi, ml/30min	<4
Filter Cake Thickness, mm	<2
Electrical Stability, volt	>400

From the results obtained, plastic viscosity (PV) of Sarapar 147 slightly decrease after ageing process compare to Sarapar 147 + Silica Nanoparticle which is increase. Silica nanoparticle increase the solid content in Sarapar 147 + Silica Nanoparticle sample which increase the plastic viscosity value from 47.5 cp (before ageing) to 50 cp (after ageing).

Plastic viscosity increase due to:

- Solid content
- Mud weight
- Emulsified water in oil based mud
- Ultra fine solid (without increase the mud weight)

And will decrease due to:

- Increasing of temperature (decreasing of drilling mud viscosity)

During drilling operation, plastic viscosity will cause several impacts such as;

- Equivalent Circulating Density (ECD). Increase of plastic viscosity will require higher ECD.
- Surge and Swab Pressure. Increase of plastic viscosity will increase the surge and swab pressure

- Differential Sticking. Increase of plastic viscosity will increase the chance for differential sticking problem due to increasing of solid content in drilling mud especially in oil based mud.
- Rate of Penetration (ROP). ROP will decrease with increasing of plastic viscosity compare to low plastic viscosity value.

Before and after ageing process of both mud samples give different output of yield point (YP). The yield points for Sarapar 147 and Sarapar 147 + Silica Nanoparticle for before ageing process are 25.5 lb/100ft^2 and 30 lb/100ft^2. Yield points for both mud samples are influence by drill solid content, lime and temperature. After ageing process with temperature 300 °F, yield points of both mud samples changed to 14 lb/100ft^2 (Sarapar 147) and 45 lb/100ft^2 (Sarapar 147 + Silica Nanoparticle). Increasing of Sarapar 147 + Silica Nanoparticle yield point cause by drill solid contents which are drill bar and silica nanoparticle. Due to difficulty to maintain the temperature of the samples, it affects significantly the yield point result. Increasing of temperature will decrease the yield point and vice versa. Increasing of yield point will result in high pressure loss while drilling mud is being circulated.

Operational impacts of the yield point are as follows;

- Equivalent Circulating Density (ECD): Increasing of yield point will increase the equivalent circulating density.
- Hole Cleaning: Drilling a large diameter hole will require high yield in order to help hole cleaning efficiency.

After ageing process for Sarapar 147 + Silica Nanoparticle mud sample has better value of gel strength for 10 second and 10 minute compare to Sarapar 147 mud sample. In oil based mud, gel strength value is influence with the buildup of fine solid particle in the mud and over treatment with organic gelling material.

In drilling operation, low gel strength of mud will not able to function effectively to suspend cutting and will drop quickly when the pump is shut down. This can lead to accumulation of cutting beds. Barite sag mostly occurs because low gel strength and will lead to inconsistency of mud weight which can lead to insufficient mud weight to balance formation pressure at the shallow section of the wellbore. High gel strength value will need high pressure to break circulation and could lead to break formation and results in lost circulation issue.

Fluid loss of Sarapar 147 + Silica Nanoparticle has significant effect in this experiment. The value of fluid loss at high temperature and high pressure (HTHP) condition is 2.4 ml compare to Sarapar 147 mud sample which is 4.8 ml. This means, the silica nanoparticle additive have effectively reduce the permeability of mud cake to prevent filtrate from penetrate into the wellbore (in real condition). Size of silica nanoparticle additive affect the volume of fluid loss and thus give 4.29 mm thickness of filter cake. Sarapar 147 mud sample has high fluid loss due to high permeability of filter cake which is 4.8 ml. The thickness of filter cake for Sarapar 147 mud sample is 3.71 mm. Both samples have bad thickness of filter cake since the standard specification of filter mud cake thickness is below 2 mm. Thus, a few improvements needed to achieve desire thickness of filter cake.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Relevancy to the Objectives

As a conclusion, different result on rheology of oil based mud samples (Sarapar 147 with Silica Nanoparticle and Sarapar 147) show that the Sarapar 147 with Silica Nanoparticle mud sample has better rheology before and after ageing process compare to Sarapar 147 mud sample.

Based on fluid loss and mud cake thickness results for both mud samples, the HPHT fluid loss of Sarapar 147 with Silica Nanoparticle mud sample has lower value compare to Sarapar 147 mud sample. In term of mud cake thickness, conventional Sarapar 147 mud sample has better thickness compare to Sarapar 147 with Silica Nanoparticle mud sample.

Overall, Sarapar 147 with Silica Nanoparticle sample has better rheology and fluid loss properties and it is suitable to use in HPHT condition.

5.2 Suggested Future Work for Expansion and Continuation

From this project, the silica nanoparticle can be further optimized in drilling fluid by changing its concentration content in drilling fluid to get better result. The future experiment should characterize physical properties of silica nanoparticle and how its react with drilling fluid. Different size of silica nanoparticle should be implemented in next experiment to determine the best size of silica nanoparticle which can influence the fluid loss of drilling fluid in LPLT and HPHT condition. The results may reduce the concentration of silica nanoparticle and narrowing the size of silica nanoparticle which is suitable to be used in drilling fluid.

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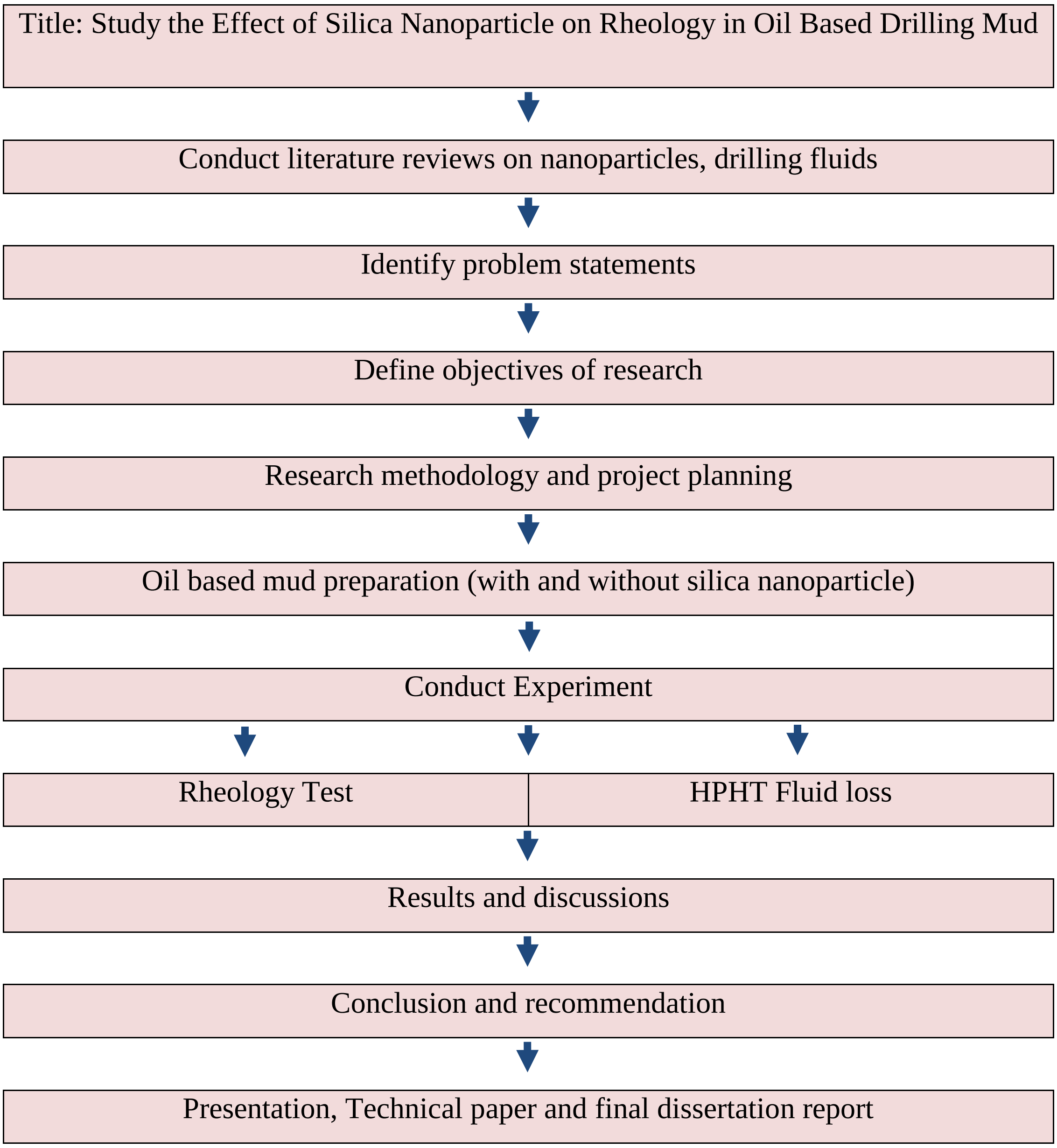
APPENDICES

Appendix I

Research Methodology



Appendix II

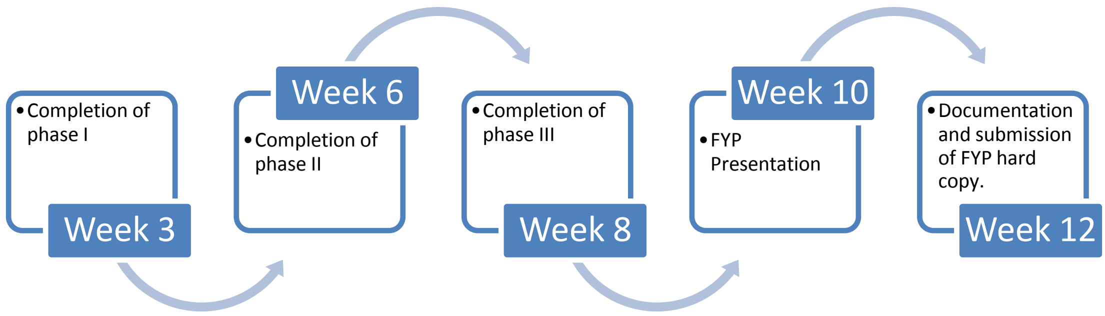
Gantt chart

Name: Mohd Fareez Bin Mustapha
Department: PE ID: 13158

No.	Project Activities	Week																												
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1	**TOPIC ALLOCATION**																													
	Selecting Topic																													
2	**PRELIMINARY RESEARCH**																													
	Literature Review																													
	Identifying Problem Statement																													
	Determining Objectives																													
	Submitting Extended Proposal																													
	Proposal Defence																													
3	**PROJECT WORK**																													
	Prepare sample (oil based mud preparation)																													
	Conduct experiment (Rheology test, LPLT Filter Press and HPHT Filter Press)																													
	Submitting Interim Draft Report																													
	Submitting Interim Report																													
	Submitting Progress Report																													
4	**PROJECT COMPILATION AND PRESENTATION**																													
	Pre-EDX																													
	Submitting Draft of Dissertation																													
	Submitting Dissertation (Soft Bound) & Technical Paper																													
	Final Oral Presentation																													
	Submitting Dissertation (Hard Bound)																													

Appendix III

Key Milestone



Tool

3.7.1 Materials

1. Base Oil – Sarapar 147
2. Additive:
    - CONFI-MUL P
    - CONFI-MUL S
    - CONFI-GEL
    - CONFI-TROL XHT
    - LIME
3. Brine:
    - Distilled water
    - $CaCL_2$
4. Weighting Agent:
    - DRILL-BAR
5. Additional Additive:
    - Silica Nanoparticle

3.7.2 Apparatus

1. Baroid Multimixer
2. The FANN Model 35A Viscometer
3. HPHT Filter Press

5. Hot Roller Oven
6. Electric Stability Kit
7. Stop Watch.