The Performance of Micromax As an Alternatives Weighting Material In High Density Synthetic Based Mud

by

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Universiti Teknologi PETRONAS
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CERTIFICATION OF APPROVAL

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May 2011

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 undertake or done by unspecified sources or persons.

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Wan Mustapai Bin Wan Hussein

Abstract

Drilling fluid (mud) is fluid used during drilling operation. It provides function such as remove cutting from well, control formation pressure and maintain wellbore stability. Weighting material is a component that controls the density of a mud system and the normal weighting agent that is used is API Barite. In high density mud system, a lot of barite is needed to achieve the desired mud weight. But having too much solid content can cause problem such as sagging and also increase the plastic viscosity which affect the equivalent circulating density (ECD). An alternative to barite is needed in high density mud system. This new weighting material should have higher density to achieve specific mud weigh with lesser amount and gives good rheological properties compared to normal barite. So Manganese Tetraoxide (Mn_3O_4) or Micromax is suggested as an alternatives. The objective of this project is to evaluate the rheological performance at 120^0F of Manganese Tetraoxide (Micromax) as an alternatives weighting material to normal API Barite in high density (17 lb/gal) oil (Sarapar 147) based mud. For the experiment, the mud system using API barite will be the base and an alternatives mud system using Micromax will be formulated with exact concentration as base. Base on initial comparison, the alternatives mud will be reformulated (make new sample) until it has similar properties (similar yield point) as the base. The rheological properties that were evaluated are; plastic viscosity (PV), yield point (YP), 6 rpm (low end rheology), gel strength and emulsion stability (ES). Base on the result, the rheological performance at 120^0F of Micromax is good to be as an alternatives weighting material to normal API Barite in high density oil based mud (specifically at 17 lb/gal and 80:20 OWR) because it has lower plastic viscosity and flatter gelling. The alternative also has high value of ES (stable emulsion) and sufficiently high value of 6 rpm (low end rheology).

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Nomenclatures

m: mass

V: volume

K: fluid consistency unit

n: power law exponent

γ: shear rate

τ: shear stress

ρ: density

μ: viscosity

Chapter 1

Introduction

1.1 Background Study

Drilling fluid is fluid that is used during drilling operation. The field term for drilling fluid is mud. As one of the major aspect in drilling, drilling fluid provide functions such as:

- Remove cutting from well – As the drill string penetrate the earth, the drill bit excavate rocks into cuttings. These cuttings need to be taken out for the wells to go deeper.
- Control formation pressure – Using hydrostatic pressure to balance the formation pressure. Unbalanced formation pressure will cause unexpected pressure influx in the wellbore that can lead to blowout.
- Maintain wellbore stability – Chemical composition and physical properties are control to maintain the wellbore stability. Mud is formulated so it is relatively inert or gives less chemical reaction on the formation. The density of mud is also need to be adjusted within acceptable range for the particular depth to balance mechanical force. The wellbore size and shape need to be maintain.
- Cool, lubricate and support the drill bit – As the drill string and the drill bit rotates and rub against the wall of the wellbore, the hydraulic and mechanical forces presences produce heat. It is essentials to cool down the drilling assembly by transferring the heat away from the source to avoid the equipments from failing rapidly. Lubrication is important to reduce torque and drag whilst the buoyant forces within the drilling fluid support the drill bit, reducing hook force on derrick.
- Transmit hydraulic energy to tools and bit – Hydraulic energy provides power for bit rotation and optimizes jet impact on bottom well.
- Seal permeable formations – Mud filtrate will enter the formation when the mud column pressure is higher than formation pressure then the filter cake is deposited on the wall of the wellbore. The mud being used in drilling operation should be formulated so that it is thin and have low permeability to limit the invasion.

Mud is basically liquid plus solid. The liquid component for a mud system is called base fluid. Base fluid can be water, mineral oil, synthetic oil and some other type of oil. While the solid components of the system are divided into several categories base on its functions. These components are called as products for the ease of discussion. Each product controls mainly a single property of the mud system. Main products in mud system are as follow:

- Viscosifier – Made of clay to control rheological properties of the mud. Rheology affects carrying capacity, slip velocity, annular hydraulics and suspending characteristic of the drilling fluid. The properties that are related to rheology are Plastic Viscosity (PV), Yield Point (YP), and Gel Strength. We also focus on low end rheology, which are represented by the reading at 6RPM in Fann 35 Viscometer.
- Fluid loss control material – Also known as filtration control material. Filtration or fluid loss is a situation where filtrate passes into the formation due to differential pressure. The fluid loss control product should block the pores or fractures on formation to avoid lost circulation. Lost circulation happen when mud flow into the formation. The solids in the mud usually form as a filter cake which prevents excessive fluid loss. For this to happen, filter cake should be thin, have low permeability (correct solids distribution) and give a low friction coefficient.
- pH control – In the formation, there are possibility of having acidic gases such as H_2S and CO_2. The presence of these gases can lead to corrosion of drilling equipment. To avoid this situation, the mud that being used to drill the wellbore must be in alkali state to neutralize these acidic gases. Right pH level also allows viscosifier (Bentonite clay) to yield faster, fully yield, and remain in suspension. In NAF mud system, the pH control product neutralize the fatty acid in the fluid, stabilize the emulsion when presence in excess.
- Weighting material – Barite is used widely as weighting material to control the mud density. Weighting material or weighting agent is a very high density, relatively inert substance and contribute large part in weighting up the mud system. In the wellbore, density of mud or mud weight is translated into hydrostatic pressure. It is very important that the hydrostatic pressure or equivalent circulating density lies between pore pressure and fracture pressure. Choosing a proper mud weight also depends on surge and swab control whilst tripping and limitation of pump capacity.

There are many types of mud system but usually it been categorized to Water Based Mud (WBM) system and Non-aqueous Fluid (NAF) system.

Water base mud system use water as the base fluid. A standard WBM comprise of water, salt, viscosifier, fluid loss control additives, shale inhibitor, and pH control additives. The WBM is cheap and gives less environmental impact but it contains water that can react with the shale formation. This can cause clay swelling and disintegration thus lead to drilling problem like stuck pipe, increase in torque and drag, washouts, and increased viscosity. The WBM also has temperature limitation because the products are normally made from polymer.

The non-aqueous fluid system is a mud system that uses base fluid other than water. Nowadays, the NAF system that usually used in drilling is the invert emulsion type. Emulsion is a mixture of two immiscible fluids in which one liquid exists in the form of very small droplets dispersed throughout the other liquid. In this invert emulsion case, oil act as the continuous phase whereas water (mix with brine) is the internal phase. Shear input through turbulent agitation can form a stable emulsion. This emulsion is stabilized by emulsifier. A standard NAF (invert emulsion) system comprise of mineral oil or synthetic oil as the base fluid, primary and secondary emulsifier, pH control additives, viscosifier, fluid loss control material and weighting material. NAF mud system is very stable over a wide range of environments. It can stand in high temperature and having a very low rate on invasion into the formation. NAF system has a lot of advantages but it gives greater environmental impact compared to WBM system, and it also consumes higher management and logistic cost.

1.2 Problem Statement

Weighting material that is normally used in drilling fluid is API barite. Barite or Barium Sulphate ($BaSO_4$) that commercially used as weighting material in drilling operation is mined and then grind to smaller and uniform size before being marketed. It's generally white or colourless and having a density of 4.28 SG. Barite is widely used because it is cheap.

In high density mud system, a lot of barite is needed to achieve the desired mud weight. In mud system, having too much solid content can cause problem such as sagging and also it can increase the plastic viscosity which affect the equivalent circulating density (ECD). Sagging can cause stuck pipe and kick. Increase in ECD can cause unstable wellbore, thus the formation having the possibility to break.

An alternative to barite is needed in high density mud system. This new weighting material should have higher density to achieve specific mud weigh with lesser amount and gives good rheological properties compared to normal barite. So Manganese Tetraoxide (Mn_3O_4) or Micromax is one of the solution because it have a specific gravity of 4.8.

1.3 Objective

The objective of this project is to evaluate the rheological performance at 120^0F of Manganese Tetraoxide (Micromax) as an alternatives weighting material to normal API Barite in high density (17 lb/gal) oil (Sarapar 147) based mud.

1.4 Scope of Work

This projects covers research on the components of NAF system, mainly on type of weighting material and also the base fluid. Some research to understand the relationships between solid content (specifically the weighting material) and mud rheology also had been done.

The experiment part of this project covers formulation and rheology check of; base sample (API Barite) and the alternatives (Micromax). As for the alternatives, the first formulation is done with exact concentration of additives as the base. Then the next formulation is adjusted so that the Yield Point (YP) is the same as the base sample.

Formulation of the mud follows the formulation for NAF system which has components such as:

- Sarapar 147 as base fluid.
- $CaCl_2$ brine.
- Primary and secondary emulsifier.
- Lime for alkalinity.
- Organophilic clay as the viscosifier.
- Gilsonite powder as the fluid loss control.
- Micromax or API Barite as weighting material.

The study of rheological performance of Micromax as an alternative weighting material should be done in different mud weight because the "high density mud" term covers mud system that have mud weight ranging from 15 lb/gal up until more than 20 lb/gal. There is also a need to test mud system with variation in oil water ratio (OWR). But due to time constraint and limited resources, the comparison is done on specific mud weight and OWR.

Mud system that was formulated for this project is invert emulsion NAF (Sarapar 147 as base fluid) with density of 17 lb/gal, 80:20 OWR, 23% $CaCl_2$ water phase salinity.

The experiment conducted covered mud mixing using Hamilton Beach Mixer. Duration of total mixing is one hour. Then the test that was conducted is rheology test using Fann 35 viscometer at 120^0F. The temperature specified is according to API Recommendation 13B-2. Electrical stability reading are also taken to measure the stability of emulsion, which an important element in NAF system. Rheological properties being considered and evaluated are:

- Plastic Viscosity
- Yield Point
- 6 rpm reading (low end rheology)
- Gel strength - 10 minutes and 10 second
- Emulsion Stability

Chapter 2

Theory and Literature Review

2.1 Theory

2.1.1 Mud Weight

Mud is formulated to achieve a desired mud weight. It is an application of general material balance equation. Material or mass balance is base on conservation of mass. This means in terms of mass the input should equal to output. In drilling mud formulation, the summation of mass of each product is equal to the total mass of the mud system. Base on this equation, if the mass, volume or density (either two) of each product is known then the final mud weight can be calculated or vice versa.

$$m_1 + m_2 + m_3 + \ldots\ldots + m_n = m_{total} \quad (1)$$

Mass is equal to Volume multiply by Density,

$$m = V \times \rho \quad (2)$$

Thus,

$$V_1\rho_1 + V_2\rho_2 + V_3\rho_3 + \ldots\ldots + V_n\rho_n = V_{total}\rho_{total} \quad (3)$$

2.1.2 Rheology

Rheology is the science of the deformation and flow of matter. When applied to drilling fluids, rheology deals with the relationship between Shear Rate and Shear Stress. Shear rate is the change in fluid velocity divided by the gap or width of the channel through which the fluid moving in laminar flow whereas shear stress is the force per unit area required to move a fluid at a given shear rate. Viscosity is the resistance of fluid to flow or deform. In mathematical definition it is a fluid shear stress divided by corresponding shear rate.

$$\mu = \tau / \gamma \quad (4)$$

Several models have been developed to give more understanding on different fluid in laminar flow. Some of the models are:

- Newtonian Model
- Bingham Plastic Model
- Power Law Model

Newtonian Model describes Newtonian fluid which the ratio of shear stress to shear rate is constant.

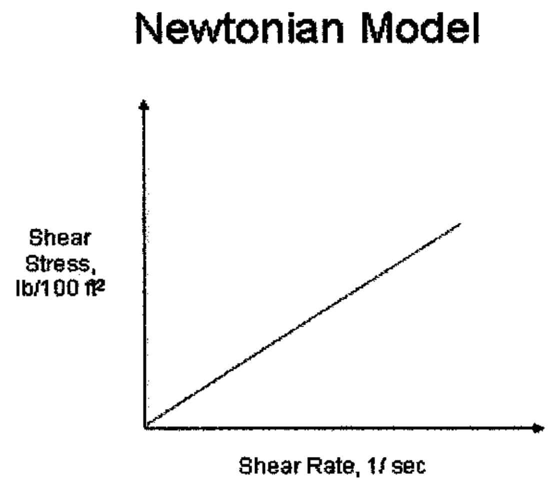

Figure 1: Graph of Newtonian Model.

For the non-Newtonian fluids, its ratio of shear stress and shear rate are not constant. The fluids contain solid particles of various sizes (normally larger than the fluid molecules) that form a structure resistant to flow.

Bingham Plastic Model is the most common model to describe non-Newtonian fluid. This model assumes that the shear rate is a straight line function of the shear stress. The point (on shear stress) where the shear rate is zero is called yield point or threshold stress. While the slope of shear stress and shear rate curve is called plastic viscosity.

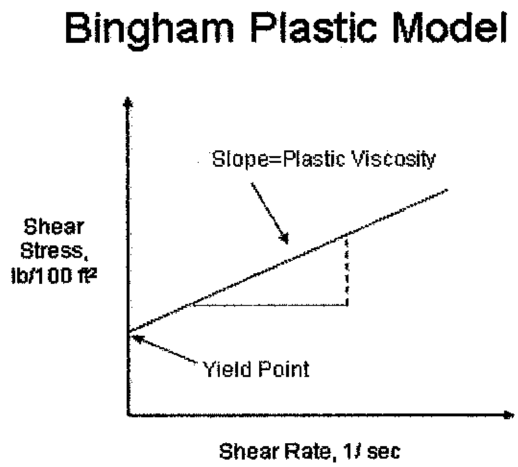

Figure 2: Graph of Bingham Plastic Model.

Another model to describe non-Newtonian fluid is Power Law Model. The shear rate and shear stress curve has the exponential equation.

$\tau = K \times (\gamma)^n$ .... (5)

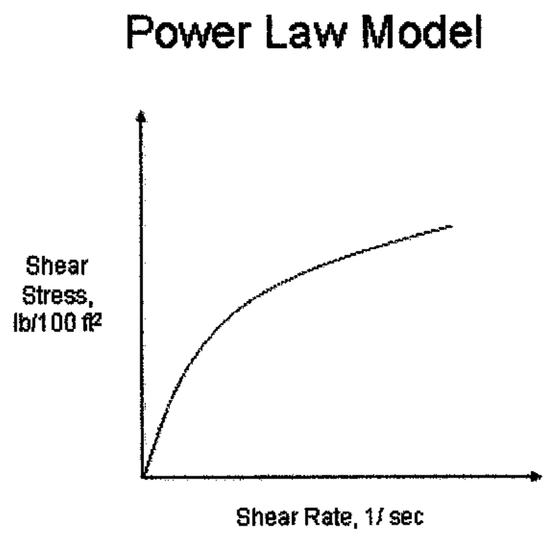

Figure 3: Graph of Power Law Model.

Plastic viscosity is resistance to flow due to mechanical friction. This friction is caused by:

- Solids concentration
- Size and shape of solids
- Viscosity of the fluid phase

Using Fann 35 Viscometer, the plastic viscosity for the mud is measured by this equation:

PV = 600 rpm reading – 300 rpm reading.. (6)

Yield point is the initial resistance to flow cause by electrochemical forces between the particles. YP is important to evaluate the ability of mud to lift cuttings out of the annulus. YP in Fann 35 viscometer is calculated by:

YP = 300 rpm reading – PV.. (7)

Gel strength is a measure of the ability of a colloidal dispersion to develop and retain gel form based on its resistance to shear. It also can be define as a measure of attraction between solids under static conditions. Base on the definition, gel strength is closely related to yield point. The gel strength is classified into two types, flat and progressive. The types are evaluated base on the difference between the readings of gel 10 minutes and gel 10 second. If there is slight difference between gel 10 minutes and gel 10 seconds, it is call flat gel which is desirable. If the difference is high then it is called progressive gel.

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

2.2 Literature Review

2.2.1 Weighting Material

Weighting material is a high specific gravity and fine divided solid material used to increase density of drilling fluid. Most common weighting material used in drilling fluid is API Barite. Small margin between pore pressure (formation pressure) and fracture pressure, small borehole size and some drilling technique requires mud system that can give low ECD. [4, 5]

Barite sag is also another challenge to be faced in designing mud system. Barite sag can cause problems ranging from lost circulation, well control, stuck pipe and poor cement jobs. Barite sag results from two physical properties of weighting agent which are the size and weight of each particle. The used of product that alters mud rheological profile to improve sag resistance is significant. [1, 2]

Alternative weighting material is developed to replace barite and Manganese Tetraoxide or Micromax is one of them. The specification data for the product are as follow:

Appearance	Reddish-brown powder
Specific Gravity	4.7-4.9
Mn content	65-70%
Fe content	Max 4.5%
Surface area	1-4 m^2/g
Average particle size	1 µm

Table 1: Technical Data of Micromax by Elkem Materials. [3]

Spherical shape particles of this product reduce the plastic viscosity by lowering the inter-particle friction. Although its particle is denser than barite particle, their much smaller size can be supported by weaker structures within the fluid hence lead to lower yield point without the risk of sagging. [1,2]

2.2.2 High Density NAF – Synthetic Based Mud System [4]

NAF is drilling fluid that has hydrophobic fluid or oil as continuous phase and if there is any water presence, it will be as the internal or disperses phase. Basically there are two type of NAF system which is water free and invert emulsion. Invert emulsion is the type where water is emulsified in oil phase and is achieved by lowering interfacial tension with surfactant, agitation to form droplets and stabilizing the dispersion by forming skin around droplets.

The base fluid in NAF system can be crude oil, diesel, mineral oil, paraffin and olefin and others. Non petroleum organic fluids are called inert fluid or synthetic fluid. This type of base fluid is more environmentally acceptable than diesel or mineral oil.

Solids or additives in a NAF are treated (normally with salts) to be oil wet. Some of the products in NAF are:

- Primary emulsifier (fatty acid) and secondary emulsifier (oil wetting agent).
- Lime – React with fatty acid to form calcium soap, and stabilizes the emulsion.
- Organophilic clay or polymeric viscosifiers to increase the viscosity.
- Asphaltic fluid loss additives consist of Gilsonite or Asphalt affect viscosity while Amine Lignite does not.
- Weighting agents to increased the density.

Chapter 3

Methodology

3.1 Project Flow Chart

Research
- Basic mud chemistry and component of NAF mud system
- Physical properties of Manganese Tetraoxide

Plan
- Design experiment procedure and condition
- Determine materials, tools and equipment for experiment

Experiment
- Formulate and mix mud system using Hamilton Beach Mixer
- Test rheological properties using Fann 35 Viscometer

Discussion
- Record data and present graphical form
- Discussion base on result and conclusion

3.2 Material and Equipment

3.2.1 Material

Materials needed for the experiment are as per 1 sample:

Materials	Quantity (gm)
Sarapar 147 oil	120-135
Primary emulsifier	4-6
Secondary emulsifier	6-12
Lime	12
$CaCl_2$ salt	10-15
Organophilic clay	2-5
Gilsonite powder	8
Micromax	480-500
API Barite	505

Table 2: List of Materials

3.2.2 Equipment

Hamilton Beach Mixer

This type of mixer is used to mix one laboratory barrel (equivalent to 350ml) of fluids. The order of chemical addition is based upon the recommended guideline or approved step. Mixing time of each chemical are recorded. There are speeds for the mixer but mixing should be done at high speed. There 2 ways to start and stop mixing action which are pulse switch or cup guide. [9, 14]

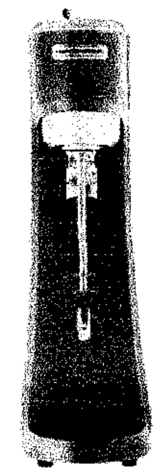

Figure 4: Hamilton Beach Mixer

Mud Balance [7]

The mud balance is designed such that the drilling fluid holding cup at one end of the beam is balanced by a fixed counterweigh at the other end, with a sliding weight rider free to move along a graduated scale. A level bubble is mounted on the beam to allow accurate balancing.

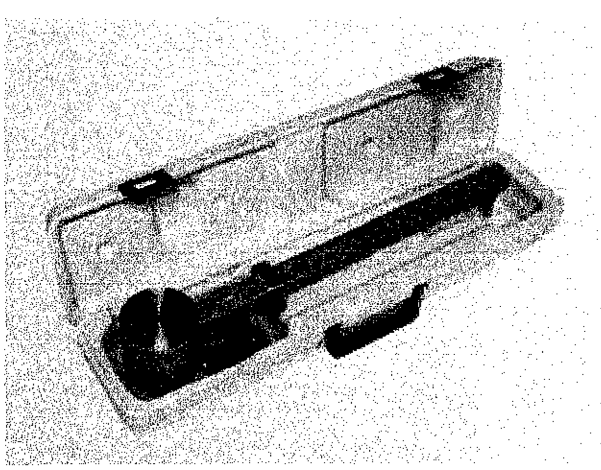

Figure 5: Mud Balance

Fann 35 Viscometer [6]

To set up Fann 35, install the bob shaft by twisting it clockwise while pushing it upward. Replace the rotor by aligning the rotor slot and groove with the lock pin in the main shaft socket. Push the rotor upward and lock it into position by turning it clockwise.

The Fann 35 has 6 different speeds, ranging from 3 rpm up to 600 rpm. The speed is determined by combination of speed switch setting and viscometer gear knob placement.

Figure 6: Fann 35 Viscometer with thermostatiscally controlled viscometer cup and thermometer

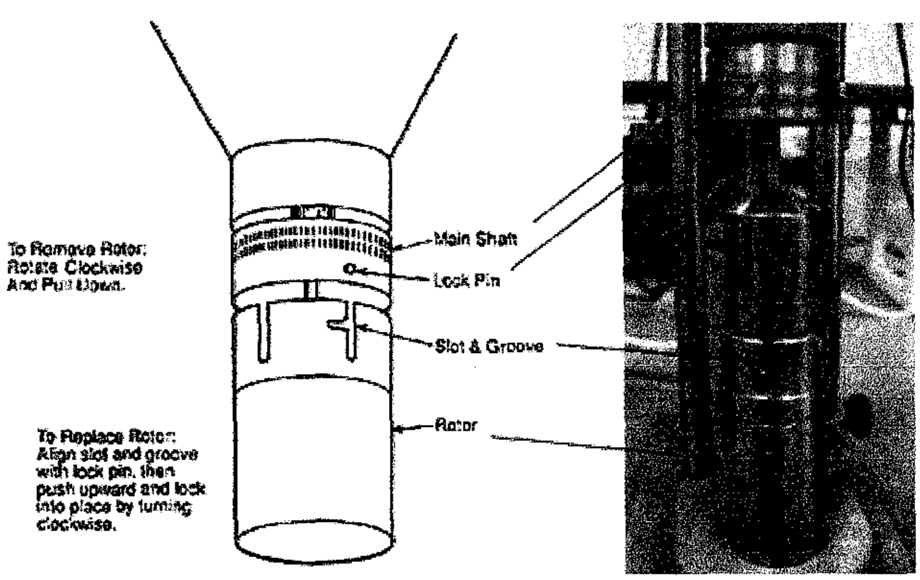

Figure 7: Fann 35 Viscometer bob and rotor

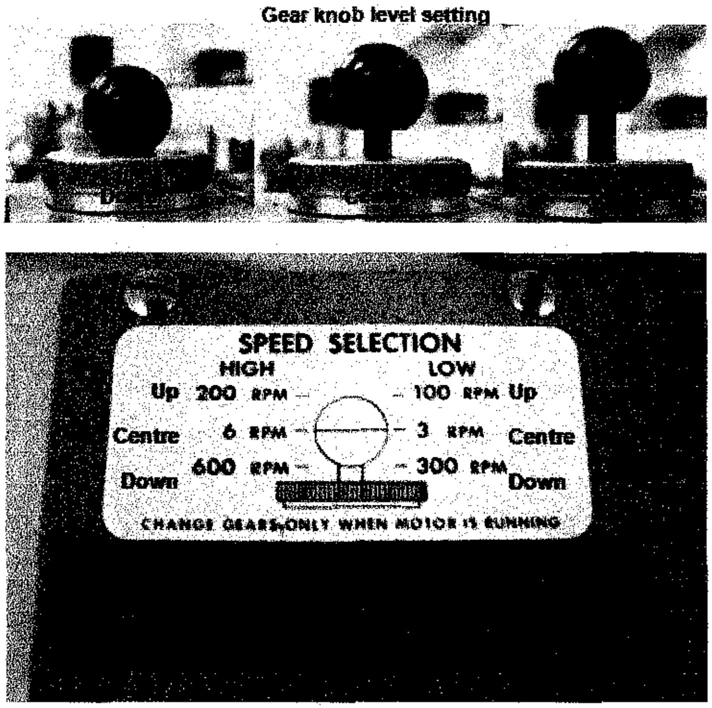

Figure 8: Fann 35 viscometer speed

Emulsion Stability (ES) Meter [8]

To calibrate the equipment is, disconnect the probe and run the voltage ramp test, the ES reading should reach maximum value. Reconnect the electrode probe and run voltage ramp test, the reading should reach maximum value. Repeat the ramp test in water and the reading should not be more than 3V. [17, 19]

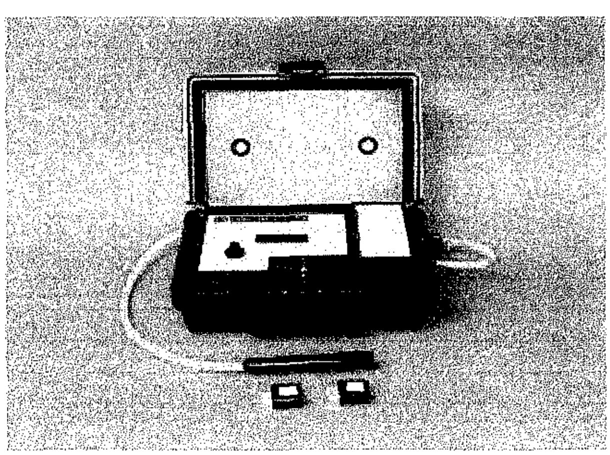

Figure 9: ES Meter

Other Equipments:

- Mud Cup (350 ml)
- Thermostactically controlled viscometer cup
- Thermometer (32^0F to 220^0F)

3.3 Procedure of Experiment

3.3.1 Mud Formulation

Base sample: 17 lb/gal, 80:20 OWR, 23% $CaCl_2$ oil based mud system using API Barite as weighting agent

Functions	Products	Concentration (lb/bbl)
Base fluid	Sarapar 147	119.83
Emulsifier	Primary emulsifier	4
	Secondary emulsifier	10
Viscosifier	Organophilic clay	4.5
Fluid loss control	Gilsonite powder	8
pH control (alkalinity)	Lime	12
Brine	$CaCl_2$	12.43
	Water	38.91
Weighting agent	API Barite	504.62

Table 3: Mud Formulation for Base Sample

Sample for alternatives: 17 lb/gal, 80:20 OWR, 23% $CaCl_2$ oil based mud system using Micromax as weighting agent

Functions	Products	Concentration (lb/bbl)
Base fluid	Sarapar 147	120-135
Emulsifier	Primary emulsifier	4-6
	Secondary emulsifier	6-12
Viscosifier	Organophilic clay	12
Fluid loss control	Gilsonite powder	10-15
pH control (alkalinity)	Lime	2-5
Brine	$CaCl_2$	8
	Water	35-45
Weighting agent	Micromax	480-500

Table 4: Mud Formulation of Alternatives Sample

*The concentration of product in alternatives sample varies because of adjusting additives concentration to get the best sample that is comparable to the base sample.

3.3.2 Mixing Procedure [5]

Sequence	Products	Time of mixing (minutes)
1	Sarapar 147	-
2	Primary emulsifier	2
3	Secondary emulsifier	2
4	Organophilic clay	5
5	Gilsonite powder	2
6	Lime	2
7	Brine (water + $CaCl_2$)	15
8	Weighting agent (API Barite/Micromax)	10
9	Additional Mixing Time	22

Table 5: Mixing Procedure

*The total mixing time is one hour.

3.3.3 Mud Density - Mud Balance

Determination of drilling fluid density: [7, 9]

1. The mud balance should be set on a flat, level surface.
2. Measure the temperature the drilling fluid and record.
3. Fill the clean, dry cup with drilling fluid to be tested; put the cap on the filled drilling fluid holding cup and rotate the cap until it is firmly seated. Ensure some of the drilling fluid is expelled through the hole in the cap, in order to free any trapped air or gas.
4. Holding the cup firmly on the drilling fluid holding cup (with cap hole covered), wash or wipe the outside of the cup clean and dry.
5. Place the beam on the base support and balance it by moving the rider along the graduated scale. Balance is achieved when the bubble is under the centreline.
6. Read the drilling fluid density at the edge of the rider toward the drilling fluid cup. Make appropriate corrections when a range extender is used.

3.3.4 Rheology - Fann 35 Viscometer

Procedure to use Fann 35 Viscometer: [6, 9]

1. Turn on the heating cup. Insert a thermometer into the well in the heating cup and preheat to desired test temperature by adjusting the thermostat control knob. A pilot light will come on when the heating jacket is at the desired temperature as selected by the thermostat control knob.

2. Place the sample into the heating cup about 2/3 full. Immerse the rotor sleeve exactly to scribed line.

3. Turn on the viscometer. Set speed to 600 rpm. Occasionally check the sample temperature by inserting the thermometer into the sample.

4. When the sample reaches the desired temperature, wait for the viscometer dial reading to reach a steady value. Record the dial reading for 600 rpm.

5. Reduce the rotor speed to 300 rpm and wait for the dial reading to reach a steady value. Record the dial reading.

6. Continue to reduce the rotor speed to measure 200, 100, 6 and 3 rpm measurement. Record all dial reading.

7. Next, stir the sample for 10 seconds at 600 rpm.

8. Turn off the viscometer and allow the sample to stand undisturbed for 10 seconds. Set rotor speed to 3 rpm.

9. After 10 seconds, turn on the viscometer to rotor speed of 3 rpm. Record the maximum dial reading after starting rotation at 3 rpm. This is the initial gel strength.

10. Re-stir the sample for 10 seconds at 600 rpm.

11. Turn off the viscometer and allow the sample to stand undisturbed for 10 minutes. Set rotor speed to 3 rpm.

12. After 10 minutes, turn on the viscometer to rotor speed of 3 rpm. Record the maximum dial reading after starting rotation at 3 rpm. This is the 10 minutes gel strength.

3.3.5 Electrical Stability – ES Meter

Procedure for electrical stability measurement: [8, 9]

1. Place the drilling fluid sample in a viscometer cup maintained at 120^0F. Record the temperature.
2. Clean the electrode probe body thoroughly by wiping with a clean paper towel. Pass the towel through the electrode gap a few times. Swirl the electrode probe in the base oil used to formulate the drilling fluid. If the base oil is not available, another oil or a mild solvent is acceptable. Clean and dry the electrode probe as before.
3. Hand stir the sample with electrode probe for approximately 10 seconds to ensure the composition and temperature are uniform. Position the electrode probe so that it does not touch the bottom or sides of container, and be sure that the electrode surfaces are completely covered the sample.
4. Begin the voltage ramp test. Follow the procedure described in the ES meter operating manual. Do not move the electrode probe during the voltage ramp test.
5. Note the ES value display on the readout device.

3.4 Gantt Chart and Key Milestone

3.4.1 Gantt Chart

Activities	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep
Research on basic chemistry and component NAF mud system		■							
Research in physical properties of Manganese Tetraoxide		■							
Design experiment procedure and condition			■						
Determine material, tools and equipme for experiment			■						
Formulate and mix mud using Hamilto Beach Mixer						■			
Test rheological properties of sample using Fann 35 viscometer						■			
Record data and present in graphical form						■			
Evaluation and discussion base on resu							■		
Research documentation				■				■	

Table 6: Gantt chart

3.4.2 Key Milestone

Key milestone	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep
Completion of paper research on NAF system and Micromax									
Completion of experiment design and selection of tools									
Completion of mud formulation mixing and test									
Completion of data record and evaluati									
Completion of project									

Table 7: Key milestone

Chapter 4

Result and Discussion

4.1 Result

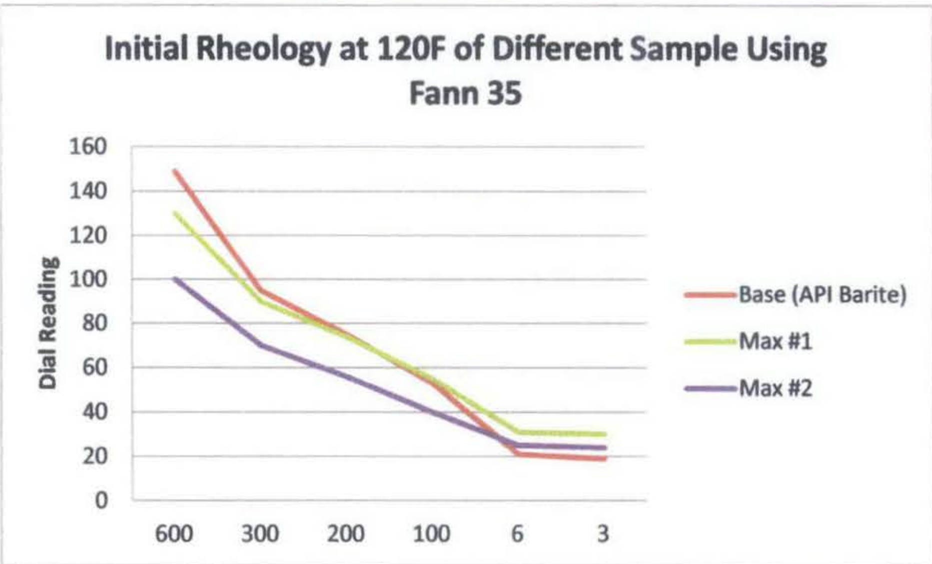

Figure 10: Initial Rheology (Fann 35)

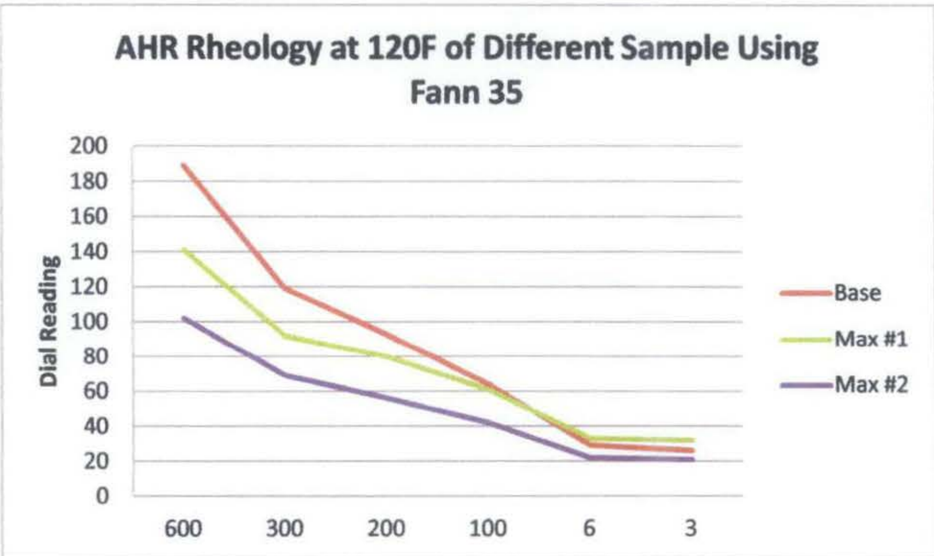

Figure 11: AHR Rheology (Fann 35)

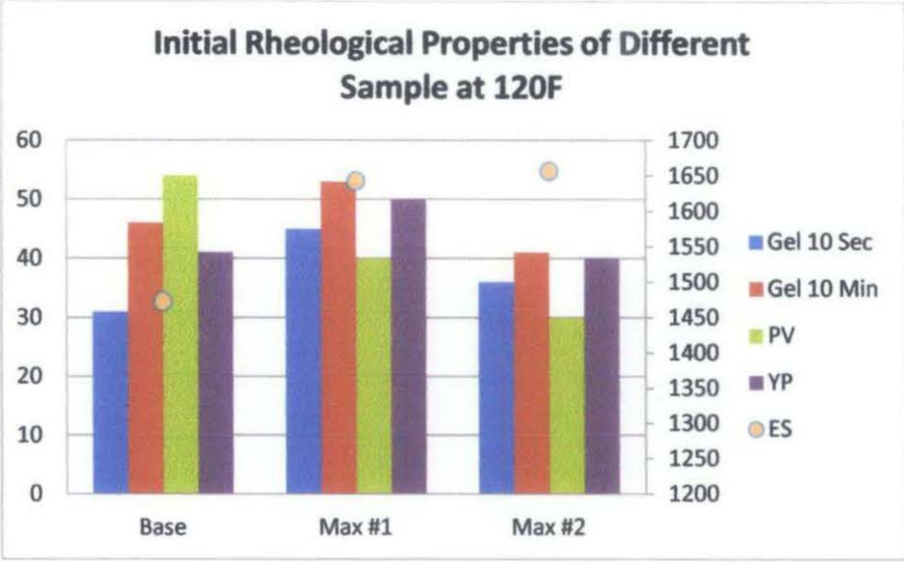

Figure 12: Initial rheological properties

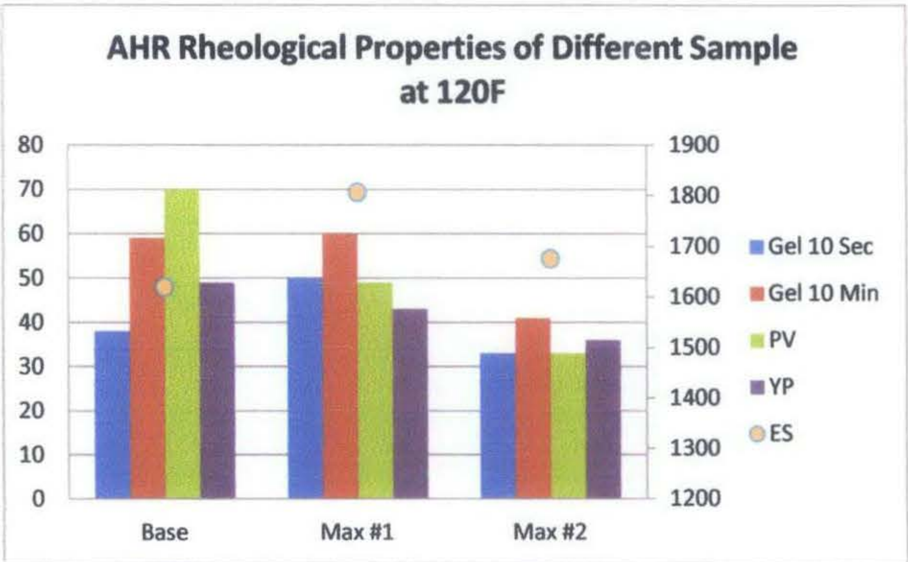

Figure 13: AHR rheological properties

Figure 14: Physical appearance of mud system using API Barite

Figure 15: Physical appearance of mud system using Micromax

4.2 Discussion

The mud system that being applied for this experiment is 17 lb/gal oil (Sarapar 147) based mud, 80:20 OWR, 23% $CaCl_2$ hot rolled at 250^{0}F for 16 hours. The rheological tests are done with Fann 35 at temperature of 120^{0}F. The temperature test is according to API standard, simulating the temperature of the mud system in the mud tank.

Max #1 is the alternative sample that has same concentration of additives as to base sample whilst Max #2 is the alternative sample that has optimized concentration of additives to get Yield Point (YP) that is comparable to base.

To formulate the Base and alternatives with same concentration (Max #1) is vital for early comparison, to see the trend of the rheological properties before optimization process.

It is important to reformulate the alternatives sample (optimization) to get YP that is similar to the base because it determines the ability of the mud to lift cutting. YP will vary for each well and the range of YP needed is pre determined before formulating a mud system.

Max #2 is the best formulation that has been done and tested which its YP is similar to the Base. Some additives are reduced in mud system that used Micromax (Max #2) to get similar ability to lift cutting as the mud system that use Barite (Base). This would represent saving in usage of additives if Micromax were used as alternatives for API Barite.

For a specified YP (which is for this case are 40), the other properties are observed:

- Plastic viscosity must be as low as possible, because it indicates the solid content in the mud system. If the solid content is high, it increases the possibility of sagging. Higher pump pressure also needed to circulate the mud and this result in high equivalent circulating density (ECD).
- The gel strength for 10 seconds and 10 minutes are compared to each other. If the difference between these two values is large, it shows that the gel is progressive. For field condition; during tripping period where the mud is in static condition, we prefer flat gelling (difference is small) because the gel strength will be relatively low after the period and it reduce the burden for the pump to remobilize the mud.

- The 6 rpm represent the low end rheology, where the velocity is low (such as in angled well or large wellbore radius). Sufficiently high value of 6rpm will suspend the solids, reduce the cutting bed formations thus avoiding mechanical stuck.
- High value of ES meter is a sign of a stable emulsion. This is important in NAF mud system. Normally a value above 600V is sufficient to indicate the emulsion is stable.

From the result, the data that is significant for discussion are Base and Max #2 because the YP is similar. We can see that for initial rheological properties (figure 12), the PV of Max #2 are 30 which is lower than PV of the Base, 54. Max #2 also has flatter gel, (gel strength 10s: 36, gel strength 10m: 41, differences: 5) compare to the Base (gel strength 10s: 31, gel strength 10m: 46, differences: 15). The 6 rpm (figure 9) of Max #2 are 25, higher than Base which is 21. The ES for both is above 1000 (stable emulsion)

The mud is then hot rolled for 16 hours at 250^0F to simulate the mud circulation at field condition. The temperature of 250^0F is considered as high temperature, and it is important that the mud system can maintain it properties even after hot rolled.

From figure 13, the YP of Base increase to 49 whiles the YP of Max #2 decrease to 36. We can see that after hot rolled the change in YP for Base is larger than the Max #2. For PV, Max #2 gives value of 33 while Base are 70 which is very high. The Max #2 still has flatter gel (gel strength 10s: 33, gel strength 10m: 41, differences: 8) than Base (gel strength 10s: 38, gel strength 10m: 59, differences: 21). The 6 rpm for Max #2 are 22 and for Base are 29. The Es value for both is still above 1000 indicating that the emulsion is still stable even after hot rolled.

Chapter 5

Conclusion and Recommendations

5.1 Conclusion

As for conclusion, base on the result and discussion, it can be said that the rheological performance at 120^0F of Micromax is relatively good to be as an alternatives weighting material to normal API Barite in high density oil based mud (specifically at 17 lb/gal and 80:20 OWR) because it has lower plastic viscosity and flatter gelling. The alternative also has high value of ES (stable emulsion) and sufficiently high value of 6 rpm (low end rheology).

5.2 Recommendations

The scope of the experiment is too small, because the density and OWR of the mud being formulated is predetermined which is 17 lb/gal and 80:20. For further study the formulation of the mud should be varied (in terms of density and OWR) to analyse whether the performance of Micromax as an alternatives weighting material are affected or not by these two factors. It is suggested that for the density variations, the mud being formulated are 15 lb/gal, 19 lb/gal and 21 lb/gal. Whilst for the OWR are 75:25, 85:15 and 95:5.

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