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. Loss circulation material (LCM) is a material that can control the problems during the drilling process which is loss circulation. The most widely used LCM in the drilling fluids is Calcium Carbonate ($CaCO_3$). In the worst case scenario, the total loss circulation can be occurring that will result no drilling fluids in the borehole and blow out would be happened. To prevent this from occurring, we need to effectively close the opening where the mud is flowing into the formation as soon as possible. But there is problem when we are using sawdust as loss circulation material (LCM) which is whether the chemical in the drilling fluids can suspend the sawdust or not and also how effective the sawdust can plug or close the opening at the formation. If the chemical did not have enough strength to suspend the sawdust, it will lead to the problem called mud sagging. The objective of this project is to evaluate the effectiveness of the sawdust as the bridging agent or loss circulation material (LCM). The rheological properties that were evaluated are; plastic viscosity (PV), yield point (YP), 6 rpm (low end rheology), gel strength and volume of fluid loss. Base on the result, the rheological performance at 120^0F of sawdust is good to be as an alternatives LCM to normal LCM which is Calcium Carbonate ($CaCO_3$) in water based mud that have low value of plastic viscosity and low volume of fluid loss. Sawdust also needs to have high value of 6 RPM reading (low end rheology) to make sure the mud is not sag.

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CHAPTER 1: Project Background

1.1.1 Background Study

Function of Drilling fluid [1]

Drilling Fluid is the fluid that is used during the drilling operation. It is very important to have the drilling fluid drilling the drilling operation it is the main preventer from the blowout by providing the hydrostatic pressure inside the wellbore. The functions of drilling fluid are:

- Remove cuttings from the well

During the drilling operation, as the drill bit penetrates the formation, the cuttings will be generated by this process. These cuttings need to be taken to the surface in order to prevent any drilling problem. Viscosity is the drilling fluid property that is important to this function. Mud must have the proper viscosity to lift the rock cuttings out from underneath the bit and carry them up the annulus to the surface. In addition, a drilling fluid must exhibit sufficient gel strength to hold the cuttings in suspension when circulation stops, and prevent them from settling to the bottom of the hole, collecting around the bit, and making the pipe stick in the hole.

- To control formation pressures

The formation pressure needs to be controlled mostly by the hydrostatic pressure by the mud. Actually we cannot control the formation pressure but we can control the mud weight in order to control the formation pressure. This function is performed by adjusting the density of the drilling fluid so that a balance is maintained between the hydrostatic pressure imposed by the column of drilling fluid and the pore pressure of the formations being drilled.

- Seal permeable formations

During the drilling operation, some of the formation is permeable and this might lead to the loss circulation. In order to prevent the loss circulation to be worst, the performing of mud cake at the borehole and also by using the loss circulation/bridging material can be used. When mud column pressure exceeds formation pressure, mud filtrate invades the formation, and a filter cake of mud is deposited on the wellbore wall. Mud is designed to deposit thin, low permeability filter cake to limit the invasion. Problems occur if a thick filter cake is formed; tight hole conditions, poor log quality, stuck pipe, lost circulation and formation damage. In highly permeable formations with large pore throats, whole mud may invade the formation, depending on mud solids size. Use bridging agents to block large opening, then mud solids can form seal. For effectiveness, bridging agents must be over the half size of pore spaces / fractures. Bridging agents (e.g. calcium carbonate, ground cellulose). Depending on the mud system in use, a number of additives can improve the filter cake (e.g. bentonite, natural & synthetic polymer, asphalt and gilsonite).

- Maintain wellbore stability

To maintain the wellbore stability, the chemical composition and physical properties can be controlled. We try to formulate the mud that is inert or give little chemical reaction on the formation that we will drill. The density of mud is also need to be adjusted within acceptable range for the particular depth to balance with the formation pressure to make sure we did not damage the formation and in order to prevent blowout from occur. Wellbore instability = sloughing formations, which can cause tight hole conditions, bridges and fill on trips (same symptoms indicate hole cleaning problems). If the hole is enlarged, it becomes weak and difficult to stabilize, resulting in problems such as low annular velocities, poor hole cleaning, solids loading and poor formation evaluation.

- Minimizing formation damage

During the drilling process, we will try to minimize the damaged at the formation especially at the pay zone. Most of the formations damaged occur because of the mud that is used during drilling operation. Some of the effects that caused by the mud are:

- Mud or drill solids invade the formation matrix, reducing porosity and causing skin effect
- Swelling of formation clays within the reservoir, reduced permeability
- Precipitation of solids due to mixing of mud filtrate and formations fluids resulting in the precipitation of insoluble salts
- Mud filtrate and formation fluids form an emulsion, reducing reservoir porosity

- Cool, lubricate, and support the bit and drilling assembly

As the drill bit and the drill string rotates and rub against the wall of the wellbore, this friction will produce heat. To avoid the equipment from failing, these heats need to be removed from the source. Air or foam drilling fluids are efficient at performing this cooling function. 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.

1.1.2 Types of Drilling Fluid

- Water
- Oil

- Bentonite/ Gel
- Barite
- Chemicals
- Salt
- Drill Solids

- ✓ **Water Base Mud**
- ✓ **Oil Base Mud**

Figure 1: Composition of mud [8]

In easy term, mud is the liquid plus solid. The liquid in the mud is called base fluid. Base fluid can be water, mineral oil, synthetic oil and some other type of oil. On the other hand, the solid in the mud consisting of several categories based on its functions or we called it as products. Each product has its own function in the mud system. Main products in mud system are as follow:

- Viscosifier – To control rheological properties of the mud mainly made by clay. 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. Due to the differential pressure inside the wellbore, the filtration or fluid loss will occur when the filtrate passes into the formation and formed the mud cake. To avoid

from loss circulation, the fluid loss control product should block or plug the pores or fractures at the formation. Lost circulation will occur when mud flow into the formation in uncontrollable manner. The solids in the mud will form a filter cake or mud cake which plug or block the pores that will prevent excessive fluid loss.

- pH control – During the drilling process, there are possibility of having acidic gases such as H_2S and CO_2 in the formation. The presences of these gases are very dangerous that can lead to corrosion of drilling equipment. To prevent this from occur, the mud that will be 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 (fully functioning), and remain in suspension. In Synthetic Based Mud (SBM) mud system, the pH control product neutralize the fatty acid in the fluid, stabilize the emulsion when presence in excess.
- Weighting material – In order to provide the hydrostatic pressure in the wellbore, we need to have the suitable density of the mud. Most widely used is barite 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. The hydrostatic pressure in the wellbore must lies between the pore pressure and fracture pressure. If the mud pressure less than pore pressure, kick will occur or if it became worst, the blowout will be happen. If the hydrostatic pressure of the mud greater than the fracture pressure, the formation will fracture. Choosing a proper mud weight also depends on surge and swab control whilst tripping and limitation of pump capacity.

1.2 Problem Statement

During the drilling operation, we will meet various problems and one of the common problems is loss circulation. It is very difficult to control the loss circulation and also require lot of money. The loss circulation can occur when the excessive pressure of mud column in the wellbore creates the fracture and the drilling fluids go into the formation or into pre-existing open fractures.

Loss circulation material (LCM) normally used in drilling fluid is Calcium Carbonate or OPTA CARB. There are lot processes that need to be done to prepare Calcium Carbonate. Most of the Calcium Carbonate that used today is extracted by mining or quarrying before undergo the chemical process. Because of lot processes that need to be done, it will lead the price of Calcium Carbonate is high which is about RM 60 to RM100/sack.

When Calcium Carbonate is used in the drilling fluids, it has the tendency to increase the density of the base mud which is can give the risky to the formation stability. If the mud weight is too high plus the hydrostatic pressure acting to the mud, the formation will break and the well will collapse. So that, the mud that return to the mud pit should be checked frequently to make sure the mud weight is not exceed the formation pressure.

The abundant waste of sawdust can be utilized as alternative loss circulation material (LCM). It can be simply prepared without undergo the chemical process that will require lot of time and money. Sawdust is biodegradable and very friendly to the environment. Besides that, the overall cost of the mud that used sawdust as LCM will be lower compared to the mud that used Calcium Carbonate as LCM. The price of sawdust is only about RM 8/sack.

1.3 Objective and Scope of Project

The objective of this project is to evaluate the effectiveness of the sawdust as the loss circulation material (LCM). The properties to be considered are:

- 6 rpm reading (Low end rheology)
- Plastic Viscosity
- Yield Point
- Volume of fluid loss

Scope of this project covers research and experiment on the material and mud system. The research that will be done covers all the information about the component of drilling fluid mainly the loss circulation material (LCM). For the experiment, it will be limited to evaluation of initial rheological properties and also the volume of fluid loss of the mud system using sawdust and mica as LCM, comparing to the mud system that using Calcium Carbonate ($CaCO_3$) as base line. The rheological properties will be tested by using Fann 35 viscometer and the volume fluid loss by using API filter press.

CHAPTER 2: Theory/Literature Review

2.1 Mud Weight [2]

Mud is formulated to achieve a desired mud weight. It is an application of general material balance equation. Material or mass balance is based 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.

$M_1 + m_2 + m_3 + \ldots\ldots + m_n = m_{total}$ .... (1)

Mass is equal to Volume multiply by Density,

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

Thus,

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

2.2 Rheology [2]

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.

$\mu = \tau / \gamma$ .... (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.

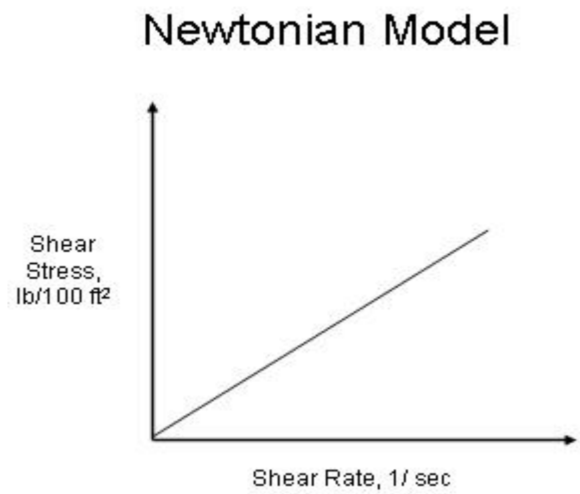

Figure 2: Graph of Newtonian Model. [3]

Newtonian fluids are those whose flow behavior calls be fully described by a single term called the Newtonian viscosity. For these fluids, examples of which include water and light oil. The shear stress is related to shear rate linearly with the proportionality constant being the Newtonian constant viscosity.

Bingham Plastic Model is the most common model to describe non-Newtonian fluid. Bingham Plastic Model is the fluids that conform to the Bingham plastic model do not have a constant viscosity and require a certain minimum stress to initiate f low. The yield point, or threshold stress, is the y intercept. Bingham Plastics include thickened hydrocarbon greases, certain asphalts and bitumen, some emulsions.

- 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.

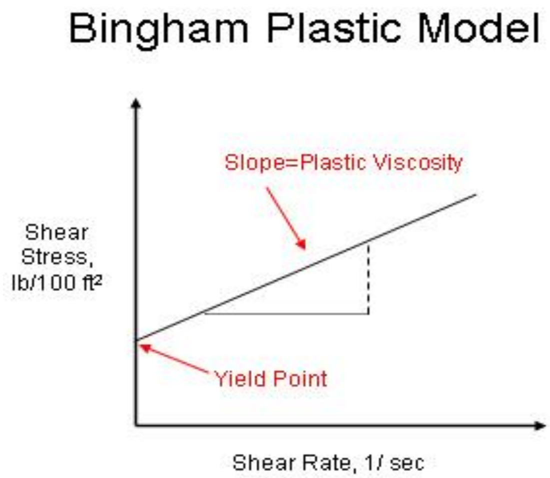

Figure 3: Graph of Bingham Plastic Model. [4]

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

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

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

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

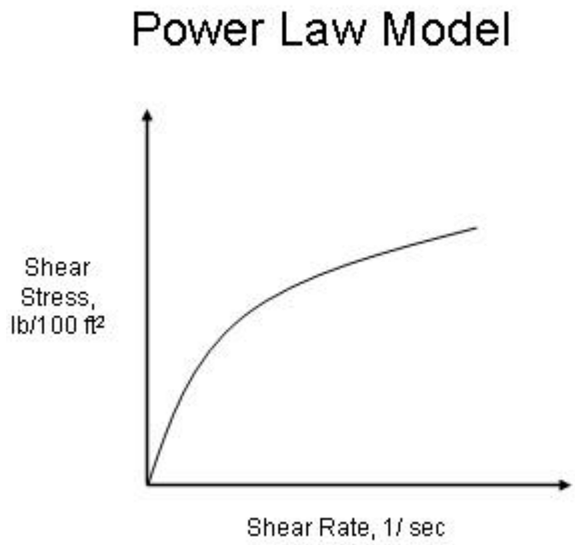

Figure 4: Graph of Power Law Model. [5]

Herschel-Bulkley Model

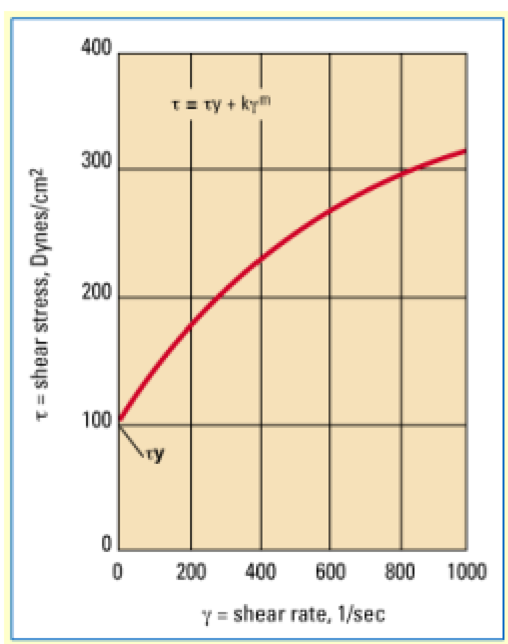

Figure 4: Graph of Herschel-Bulkley Model. [6]

It is also known as yield Power Law. A fluid described by a three parameter rheological model. A Herschel-Bulkley fluid can be described mathematically as follows:

$$\tau = \tau_y + K(\gamma)^n$$

Much clay water behaves as Herschel-Bulkley fluid.

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.

2.3 Literature Review

During drilling for example in the reservoir section which contains highly permeable formation, the drilling fluids tend to enter and loss to the formation. To prevent this problem happened, we can add some material to plug the formation and prevent the drilling fluids from loss to formation.

Four main formation types which losses occur: [7]

i) Unconsolidated or Highly Permeable (matrix losses)
ii) Naturally fractured
iii) Induced Fractured
iv) Cavernous (mainly worst losses occur)

Four types of loss rate: [7]

i) Seepage losses < 25 WBM or 10 OBM bbls/hour
ii) Partial losses 25 – 100 WBM or 10 – 30 OBM bbls/hour
iii) Severe losses > 100 WBM or > 30 OBM bbls/hour
iv) Complete losses No returns to surface

The material that we used to stop the loss circulation should not change the mud properties and also should not damage the formation. For my project, I am going to use sawdust as the loss circulation material because it has the flat shape and also did not affect the chemical chain inside the mud system. The most important thing is that the sawdust is bio-degradable and very friendly to the environment.

CHAPTER 3: Methodology

3.1 Project Methodology

Research

- Basic mud chemistry and component of Water based mud
- Sawdust as Loss Circulation Material (LCM)

Plan

- Design experiment procedure and condition
- Determine tools and equipment for experiment
- Formulate mud system - density, mud component, LCM and others

Experiment

- Mix mud according to formulation
- Test rheological properties using Fann 35 Viscometer
- Test the volume of fluid loss by using API Filter Press

Discussion

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

Equipment	Quantity
Oven	1
Morter Grinding	1
Sieve Shaker	1
Hamilton Beach Mixer	2
Mud Cup	2
Thermo Cup	2
Fann 35 Viscometer	2
API Fluid Loss	2
Mud Balance	1

Table 1: Equipment and tools for testing the mud

3.2 Mixing Procedure [2]

<u>Water Based Mud</u> (Total mixing time is 45 minutes)

Products	Mixing order	Mixing time, min
Make up water	1	-
Soda ash	2	2 minutes each
Salt	3	2 minutes each
Bentonite	4	2 minutes each
Fluid loss additives	5	5 minutes each
Viscosifiers	6	5 minutes each
Weighting agent	7	2 minutes each
pH control	8	2 minutes each
Contaminants; Rev dust, OCMA Clay	9	2 minutes each

Table 2: Mixing procedure for WBM

3.2.1 Mud Testing[2]

Density of the mud

Figure 6: Mud balance

The Mud Balance is used for mud weight determinations and is the recommended equipment in the API standard procedures for testing drilling fluids. The mud balance is accurate to within +/- 0.1 lb/gal (or 0.5 lb/ft3, 0.01 g/ml , 10 g/l). It is designed such that the mud cup, at one end of the beam, is balanced by a fixed counterweight at the other end, with a sliding weight rider free to move along the graduated scale. A level bubble is mounted on the beam to allow accurate balancing. This, most basic, of mud properties is often reported incorrectly due to the use of an inaccurately calibrated mud balance. The time to check the balance is not when a well control situation develops but on a routine daily basis. The mud test kit will contain both standard mud balances and a pressurized Halliburton mud balance. Both types are calibrated by weighing distilled water at 70 °F (21.1 °C) and obtaining a reading of 1.00 SG / 8.33 lb/gal. If this is not the case adjust the balance by adding or removing lead shot as required.

Experience has shown that, under normal drilling conditions, the standard balance gives the same reading as the pressurized balance. For ease of use, therefore, the standard balance may be routinely used to measure mud density. At the first indication of gas or air entrapment in the mud only the pressurized balance should be used. On a tourly basis the pressurized balance will be used to confirm it is reading the same as the standard balance.

3.2.2 Marsh Funnel [2]

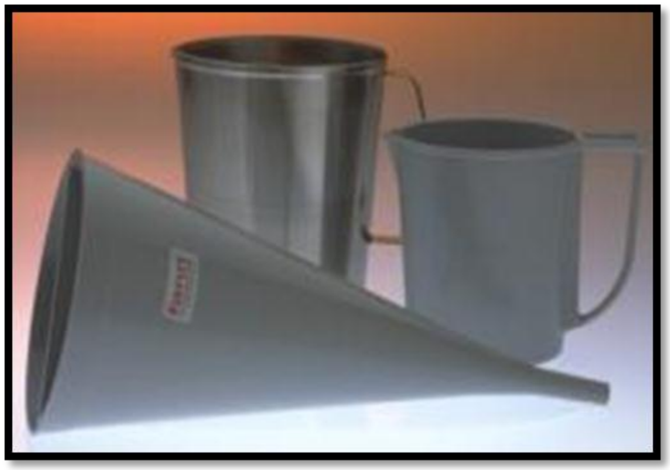

Figure 7: Marsh funnel

The Marsh Funnel Viscometer is used for routine viscosity measurements. The results obtained are greatly influenced by rate of gelation and density. The latter varies the hydrostatic head of the column of mud in the funnel. Because of these variations, the viscosities obtained cannot be correlated directly with those obtained using the rotational viscometers, and therefore can only be used as an indicator of mud stability, or relative changes to mud properties.

The funnel viscosity is a good quick guide to whether water based mud is thickening or thinning. However further analysis of rheology and solids content will be required before embarking on any treatment program. The result is temperature dependent but not to the same degree as SBM. The funnel viscosity is, therefore, a more relevant indicator of trends in a WBM.

3.2.3 Rheology Test [2]

Figure 8: Fann 35 Viscometer

The rheology test is carried out on the viscometer unit. The viscometer has 6 different speeds (600, 300, 200, 100, 6 and 3 rpm). At each speed, a reading will be taken and then from these 6 readings, the Plastic Viscosity (PV) and the Yield Point (YP) can be determined. PV is the resistance to flow due to mechanical friction of the properties. It is affected by the solids concentration, size and shape of the solids and the viscosity of the fluid phase in the mud. The higher the volume percent of solids, the higher the surface area and thus the higher the PV will be.

YP is the initial resistance to flow caused by electrochemical forces between the particles. The charges on the surface of the particles dispersed in the fluid phase are what cause the electrochemical forces to present. YP is highly dependent on the surface properties of the mud solids, the volume concentrations of the solids, and the ionic environment of the liquid surrounding the solids.

PV indicates the flow characteristics of the mud when it is moving rapidly, whereas YP indicates the flow characteristics when the mud is moving slowly or at rest. In both cases, higher values indicate a more viscous mud. The units for PV is entipoise (cP), whereas for YP is lb/100 ft^2.

The gel strengths readings are also determined from the viscometer. The gel strengths will indicate the behavior of the mud over time when it is in static condition, that is, when the mud circulation is stopped. Gel strength is run for 10 seconds and 10 minutes. The difference between the two readings will then be used to indicate whether the mud has progressive gel or not. Progressive gel is a term used when the difference between the two gel strength readings are too large, which is undesirable. Progressive gels are caused by high solids concentration which leads to flocculation. If flocculation occurs, there may be a need to increase the power of the pump to circulate the mud again after being at rest, which is cost consuming.

Most drilling fluids have critical yield stress which must be exceeded before flow is initiated. This characteristic follows the Bingham Plastic model closely. However, the Bingham model could not accurately describe the fluid rheological characteristics in all drilling situations due to its inability in describing fluid flow over a long shear rate range. In this case, the Power Law model is then thought to be more accurate in describing the flow characteristics of drilling fluids over the shear rate ranges experienced in the wellbore. The only downfall of this model is that it does not fully describe drilling fluids as it does not have a yield stress and underestimates low shear rate viscosity. Due to these reasons, a modified Power Law (Herschel-Bulkley model) is produced from the results of the previous models (Bingham, Power Law, and Newtonian).

The diagram below shows the differences between the Bingham Plastic, the Power Law and the modified Power Law models. The modified Power Law which is located in between the two other models shows more resemblance to the flow profile of a typical drilling mud.

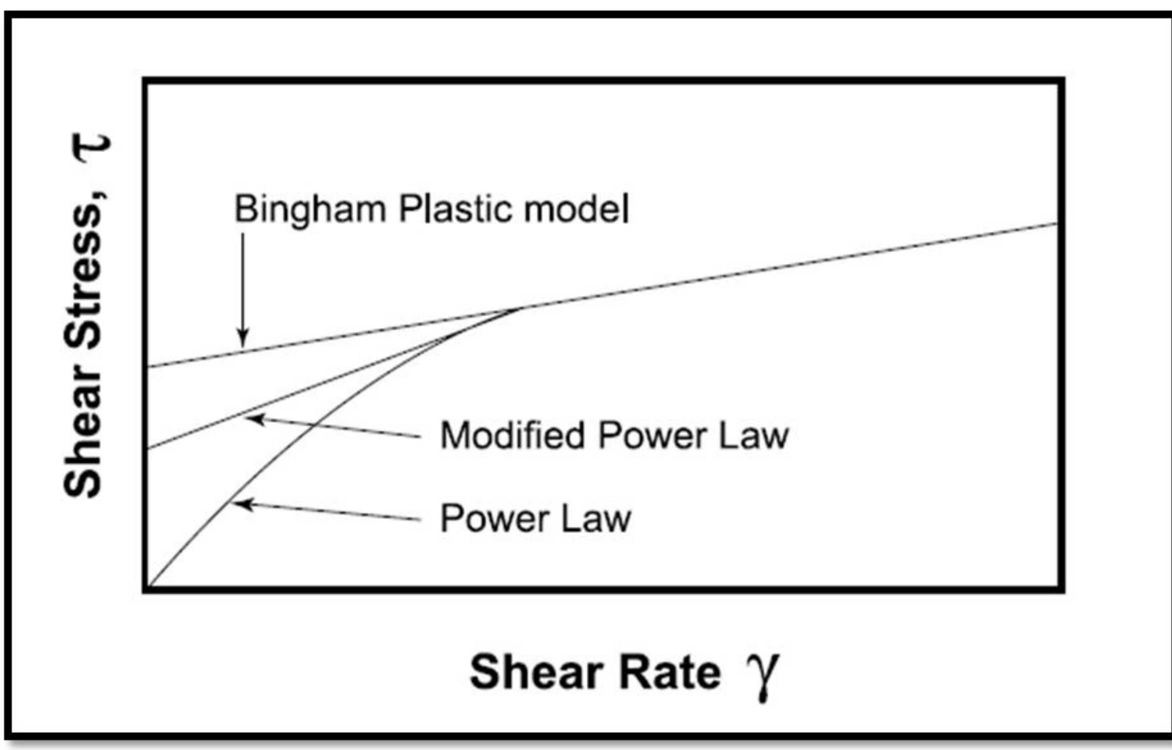

Figure 9: Comparison between Bingham Plastic, Modified Power Law and Power Law models

3.2.4 API Filtrate Test [2]

Figure 10: API filter press

The API Filtrate Test is performed to study the fluid loss characteristic in a mud. This test is carried out at room temperature with 100 psi (690 kPa) differential pressure. Even though this condition does not reflect the downhole conditions, experience has shown that this test is a reliable way of measuring the amount of fluid loss from the mud to the wellbore formation at any given moment. The thickness of the filtrate cake is also considered in conjunction with the amount of the fluid loss collected. Lab testing experience has also shown that solids content in the mud is the most influencing factor. A low solids polymer mud may have a relatively high fluid loss but the filter cake is almost non-existent, whereas a high solids mud may have a lower fluid loss but a much thicker filter cake.

No.	Detail / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic														
2	Preliminary Research Work							B							
3	Submission of Extended Proposal							R							
4	Proposal Defend							E							
5	Project Work Continues							A							
6	Submission of Interim Draft							K							
7	Submission of Interim Report														

Figure 11: Gantt Chart for FYP 1

Detail / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Prepare and sieve the sample														
Lab session and obtained the data														
Analysis on the result and performance of the mud														
Submission of Progress Report							B							
Seminar (compulsory)							R							
Poster Exhibition							E							
Pre-EDX & draft Final Report submission							A							
Submission of Technical Paper							K							
EDX														
Oral Presentation														
Submission of Final Report														

Figure 12: Gantt Chart for FYP 2

CHAPTER 4: Result and Discussion

Before mixing and checking the rheological properties of the mud, the sample of sawdust and sand sample should be prepared. The sand sample and sawdust had been put into the oven to remove the moisture at 80^0C for 12 hours.

After took out the sawdust and sand sample from the oven, all the samples had been sieved to 300 µm (fine), 425 µm (medium) and 600 µm (course).

Then, the mixing of the mud took place and the rheological properties can be checked by using Fann35 Viscometer.

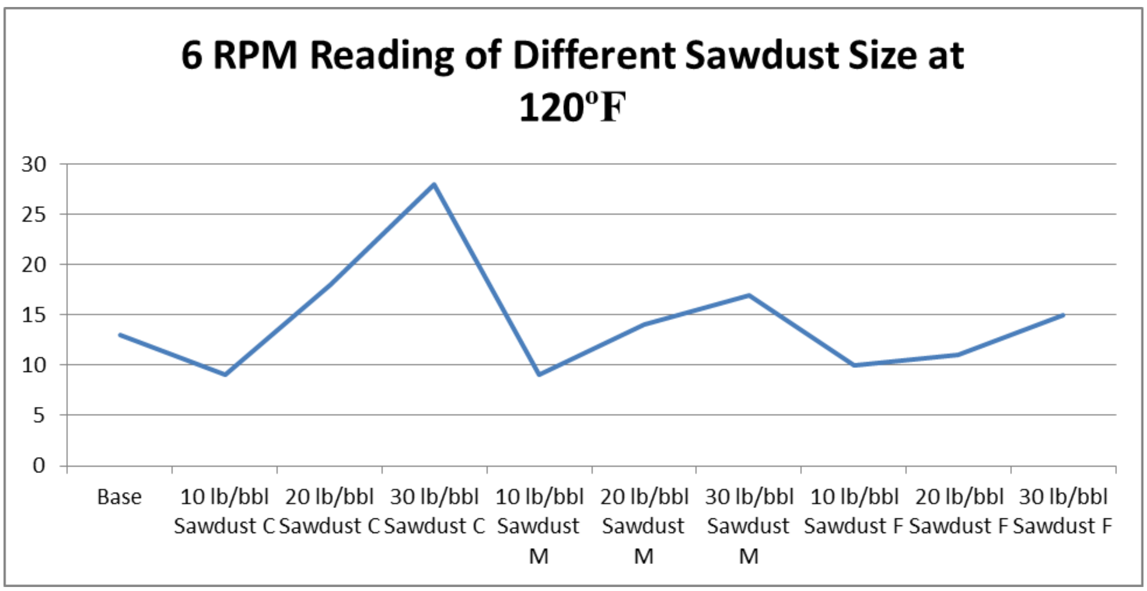

Figure 13: 6 rpm reading of different sawdust size at 120^0F

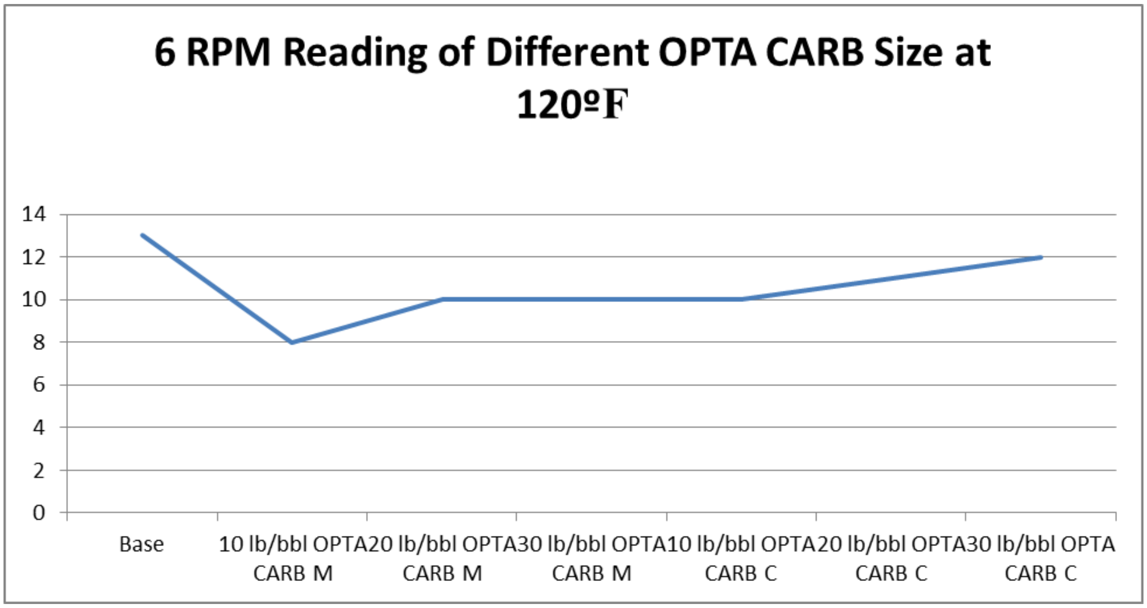

Figure 14: 6 rpm reading of different OPTA CARB size at 120^{0}F

From theboth 6 rpm reading chart, all the value of 6 rpm is more than 8 that is good for this mud system because 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.

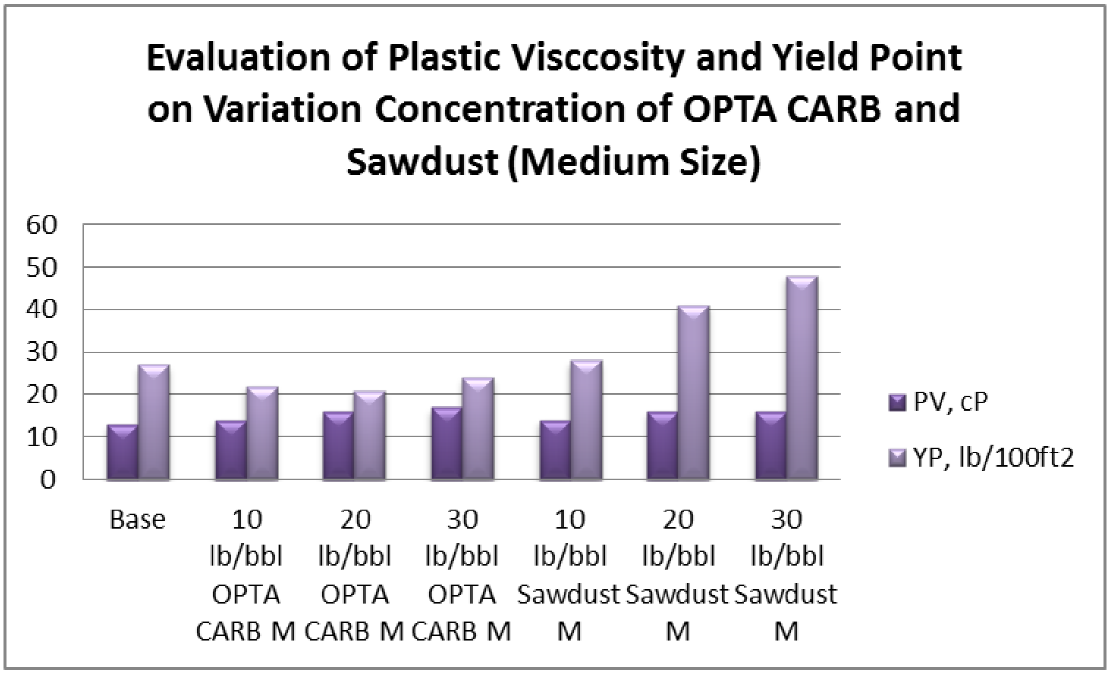

Figure 15: PV and YP value of OPTA CARB and sawdust (medium size)

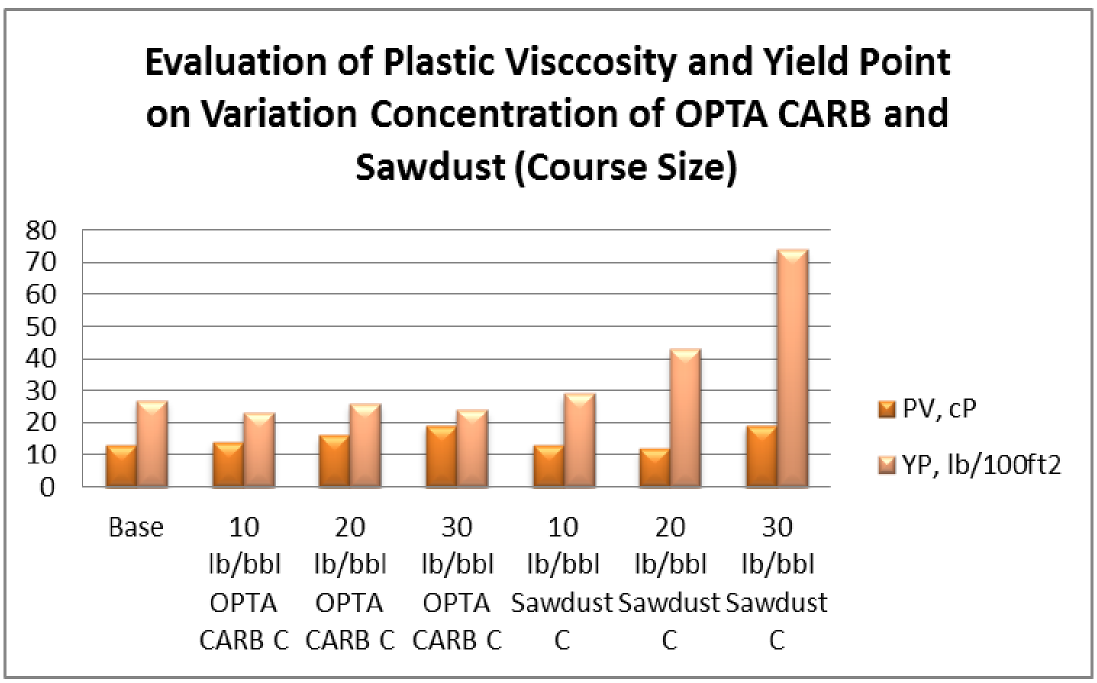

Figure 16: PV and YP value of OPTA CARB and sawdust (course size)

The rheological properties of the mud are tested by using Fann35 Viscometer at 120^0F. This temperature is according to API standard, simulating the temperature of the mud system in the mud tank.

The value of Plastic Viscosity (PV) of the mud that used medium size of OPTA CARB as loss circulation material (LCM) are in the range of 14 to 17 cP which is low and good for the mud system.

The same case goes to the mud that used medium size of sawdust as LCM when the value of plastic viscosity are in the range of 14-16 cP which is not far away from the mud that used medium size of OPTA CARB as LCM.

The value of Yield Point (YP) of the mud that used medium size of OPTA CARB as LCM is in the range of 22-24 lb/100ft2 which is good for the mud system that required the value of YP is between 20-30 lb/100ft2.

On the other hand, the value of YP of the mud that used medium size of sawdust as LCM is in range of 28-48 lb/ft2 which is not very good value for the mud system. The value of YP is keep increasing when the amount of sawdust is added from 10 lb/bbl to 30 lb/bbl.

For the mud that used course size of OPTA CARB as LCM, the value of Plastic Viscosity (PV) of the mud that is in the range of 14 to 19 cP which is low and the value is almost the same with the mud that used medium size of OPTA CARB.

The mud that used course size of sawdust also gave the low amount of PV which is in the range of 13-19cP and is good for the mud system that required the value of PV lesser than 20 cP.

The value of Yield Point (YP) of the mud that used course size of OPTA CARB as LCM is in the range of 23-26 lb/100ft2. But, the different case occur for the mud that used course size of sawdust as LCM because the value of YP is keep increasing with the increasing amount of sawdust in the mud. The worst, mud that used 30 lb/bbl of course size of sawdust gave the value of YP is 74 lb/100ft2 which is too viscous and can damage the formation.

- 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 high value of YP can give the indicator of the mud is viscous mud. The very viscous mud has the risk to break the formation and the drilling process also will require lot of power to rotate the drill string.

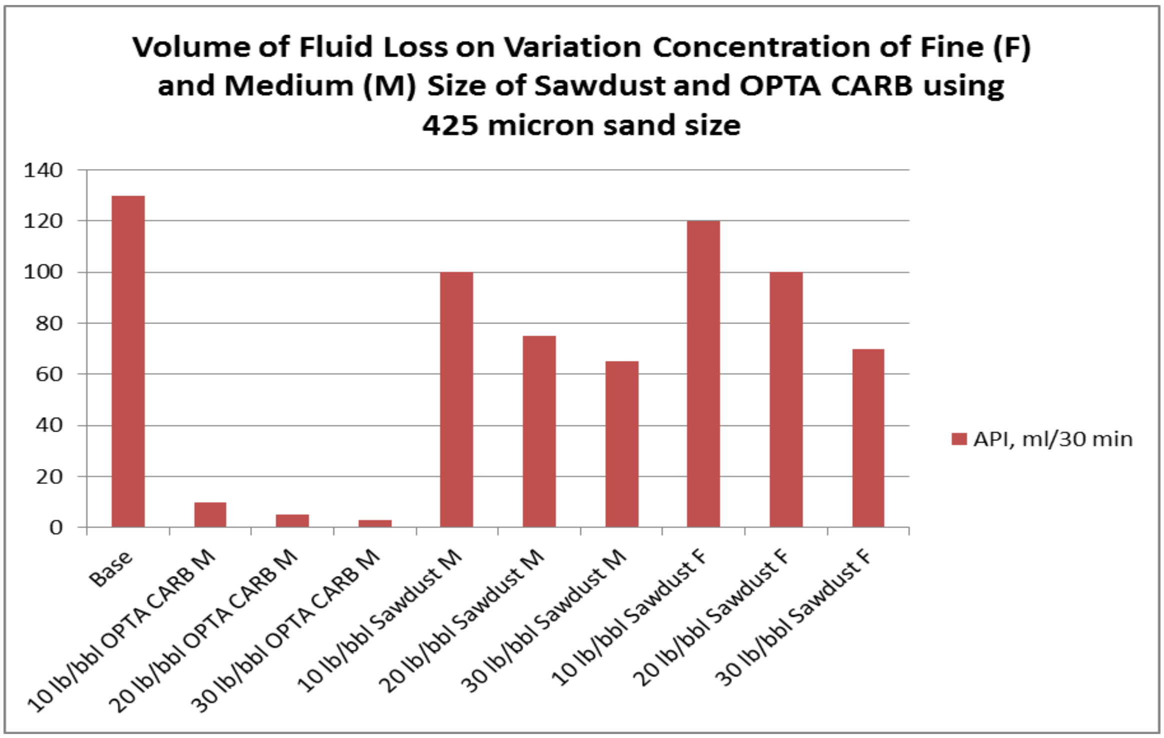

Figure 17: Volume of fluid loss at 425 micron sand size

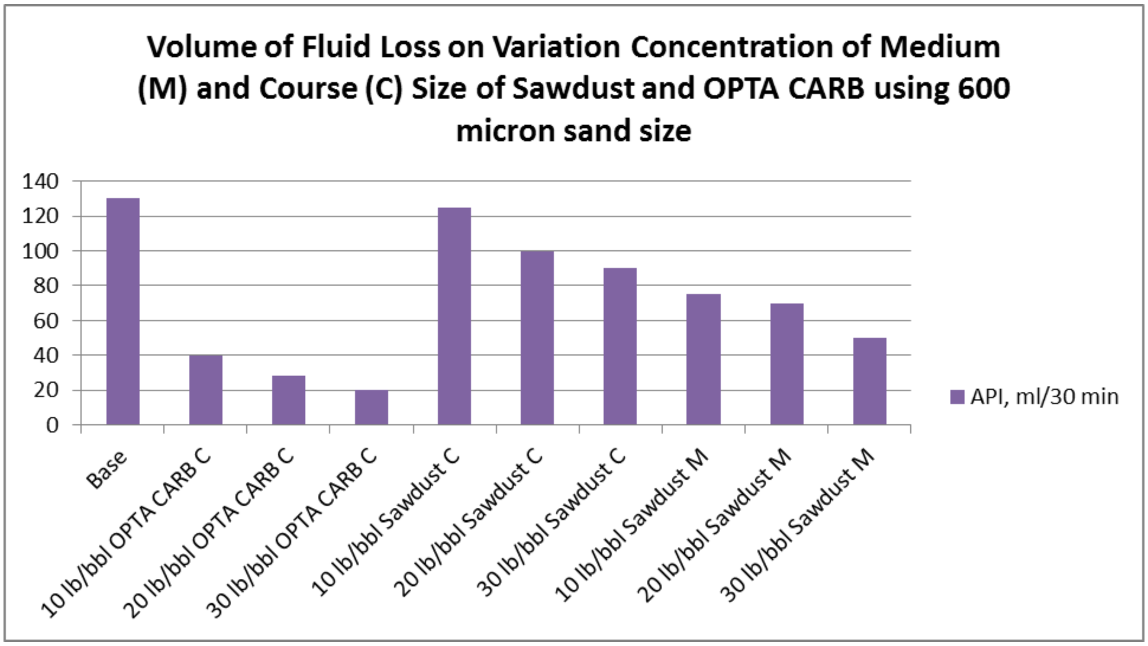

Figure 18: Volume of fluid loss at 600 micron sand size

The volume of fluid loss of the mud is tested by using API filter press with some modification by replacing the filter paper with the different sand size sample. The sand sample will act as the formation during the test.

From the chart, there is no data of the volume of fluid loss for the 300 micron sand size because when the base mud (without LCM) is tested using API filter press, there is no fluid loss. So that, the test should be proceed to the next sand sample which is 425 and 600 micron meter.

For the sand sample of 425 micron, there are three different types of LCM with different amount of LCM for each sample. 10 lb/bbl medium and fine size of sawdust give highest volume of fluid loss and almost fail to plug the formation. As the concentration of medium and fine sawdust is added to 20 lb/bbl and 30 lb/bbl, the volume of fluid loss become lesser.

It shows that the mud that used 10 lb/bbl medium and fine size of sawdust did not have enough amount of LCM to plug the formation to prevent mud from loss to formation.

For the mud that used medium size of OPTA CARB as LCM, the volume of fluid loss for the sand sample of 425 micron is low even though only 10 lb/bbl of medium size of sawdust is used. When the concentration of medium size OPTA CARB is added to 30 lb/bbl, the volume of fluid loss lower compared to the 10 lb/bbl of OPTA CARB.

The same problem goes to the volume of fluid loss that using 10 lb/bbl course size sawdust that tested on 600 micron sand size. The volume of fluid loss is very high and almost has the same value of the fluid loss of the base mud that did not use any LCM. By increasing the concentration of sawdust from 10 lb/ bbl to 20 and 30 lb/bbl, the volume of fluid loss had shown the trend to have little volume of fluid loss.

The mud that used medium size sawdust that tested on 600 micron sand sample give lesser volume of fluid loss compared to the mud with the course size sawdust. This is mainly because of the medium size sawdust can effectively plug the 600 micron sand sample compared to the mud with course size sawdust.

For the mud that used course size of OPTA CARB as LCM is still give the lower volume of fluid loss compared to the mud that used course and medium size of sawdust that tested on 600 micron sand sample.

From the chart, all the volumes of fluid loss that tested on 425 and 600 micron sand sample become lesser when the concentration of OPTA CARB and sawdust are increased from 10 lb/bbl to 30 lb/bbl. The volume of fluid loss that used OPTA CARB as LCM give the lower value compared to the mud that used sawdust as LCM both in 425 and 600 micron sand sample.

Chapter 5: Conclusion

5.1 Conclusion

From all the result that I had obtained, there are some properties of the mud that used sawdust as LCM is beyond the acceptable value. Especially from the value of Yield Point of all the mud that used 30 lb/bbl as LCM which give the value more than 40 lb/100ft2 that can give the indicator the mud is very viscous and not suitable to use in drilling fluids.

The volume of fluid loss of the mud that used sawdust as LCM also did not give the good amount compared to the mud that used OPTA CARB as LCM especially all the mud that used 10 lb/bbl sawdust as LCM and the volume of fluid loss obtained almost the same with the base mud that did not use any LCM. But from the trend, we can see that the volume of fluid loss of the mud that used sawdust as LCM become lesser when the concentration of sawdust is added.

When the concentration of sawdust in the mud is added, the volume of fluid loss will give the lesser amount but it will lead to the other problem which is the value of Yield Point that goes very high and make the mud very viscous to be used.

The mud that used OPTA CARB as LCM give the better value of Yield Point and volume of fluid loss compared with the mud that used sawdust as LCM. The value of 6 rpm reading and Plastic Viscosity of the both mud almost have the same performance.

5.2 Recommendation

The scope of experiment is too small because the density of the mud for this project is 10 lb/gal. For further study, the formulation should be varied with the concentration of sawdust and also the density of the mud to analyze whether sawdust as alternatives loss circulation material is affected with these two factors. It is suggested to use 20 lb/bbl to 60 lb/bbl of sawdust in 11 lb/gal to 13 lb/gal and checked their rheology properties, volume of fluid loss by using API filter press and volume of fluid loss by using permeability plugging apparatus (PPA).

Chapter 6: References

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Chapter 7: Appendices

Pictures of The Project