Investigation on Lost Circulation Materials (LCM) Derived From Durian Peel Waste For Drilling Fluid Formulation

by

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Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved by,

(Pn Mazlin Idress)

UNIVERSITI TEKNOLOGI PETRONAS

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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.

Raieza

RAIEZA HANIM RAHIMAN

ABSTRACT

This report concerns on **investigation on lost circulation materials (LCM) derived from durian peel waste for drilling fluid formulation**. The project mainly aims to study the effectiveness of using durian peel as LCM additives to prevent the lost circulation problem.

The paper discusses the literature reviews of the lost circulation problems, the lost circulation materials and the characterization of the parameters of drilling fluid. It also confers the methodologies for LCM to resolve severe lost circulation problems and designing the mud samples, the mud densities, the rheological tests, and the filtration performance volume tests. Tests have been conducted in accordance with the API 13 B and the related equipments were mixer, mud balance and viscometer. Properties measured through this experiment such as density, plastic viscosity, yield point, 10 seconds and 10 minutes gel strength and filtration rate. Particle size of 150 microns to 300 microns and its amounts were the variables used in the experiments.

Considering the fact that lost circulation is one of the most serious and expensive problems facing the drilling industry, lost circulation materials should be low-cost waste products, and in this case it is the durian peel fibers.

Overall, the results show that as the amount of additives is increased, the density, plastic viscosity, and yield point increased as well. Meanwhile, the gel strength and the filtration rate show a reverse relationship with the added amount and went decreased as the amounts of additives were added progressively. The 150 microns of particle size was found to be more favorable to be used in drilling fluid compared to 300 microns. The suitable concentration obtained for durian peel is 71.43 kg/m^3.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND STUDY

There are various problems that might occur during drilling such as stuck pipe, fishing and lost circulation. Lost circulation occurs when a very porous and permeable formation is encountered in the subsurface. The drilling mud flows into the formation without building up a filter cake. During lost circulation, more mud is being pumped down the well than is flowing back up. Considering that lost circulation is one of the most serious and expensive problems in drilling, this project will concentrate more on this issue and an effective strategy by using the lost circulation material, specifically targeted to solve the problem will be formulated. Lost circulation problems are not confined to any one area; they may occur at any depth, regardless of whether the drilling mud is weighted or not. (H.CH Darley, 1988)

Lost circulation unfavorably affects the overall drilling operation by:

- The loss of hydrostatic head that may result in a well-control situation.
- The reduction in the pressure gradient may lead to wellbore stability, which could result in hole collapse and/or stuck pipe.
- Loss of litho logical information since there is no drilled cutting return to surface.
- Possibility of Sidetracking.
- Possibility of losing the hole.
- Increase in costs due to fighting the mud loses.

Due to this reason, an investigation on the lost circulation should be put in place. This will ensure that, when losses are encountered, the proper treatments are executed competently and methodically, such as using a lost circulation material for this case.

Many different types of bulk materials have been used to prevent loss of mud to the formation or to restore circulation. They may be divided into four categories (George R. Gray, 1988):

1. Fibrous materials.
2. Flaky materials.
3. Granular materials.
4. Slurries whose strength increases with time after placement.

These lost circulation materials (LCM) are challenged at their limits of effectiveness to meet the goals of sealing the severely fractured, vugular and cavernous formations. LCMs that are capable of such requirements under ideal conditions may be hampered in performance by the temperatures and chemistry encountered. And in this project, I investigated on LCM derived from **durian peel** fibrous waste for the drilling fluid formulation.

1.2 PROBLEM STATEMENT

Lost circulation occurs when the drill bit encounters natural fissures, fractures or caverns, and mud flows into the newly available space. Lost circulation may also be caused by applying more mud pressure (drilling overbalanced) on the formation than it is strong enough to withstand, thereby opening up a fracture into which mud flows. In the oil industry, and, of course, to the local oil company, most of the commercial lost circulation materials have been tested with different levels of success. The trend now is to rethink different ways to better tackle the mud losses intricate problem and reduce drilling costs.

Various methods and means have been used to restore circulation of the drilling fluid when a lost circulation occur and such methods usually entail the addition of "lost circulation" materials or formation sealing agents to a drilling fluid to thereby form a lost circulation material fluid.

There is a need for a lost circulation material that is low in cost and effective in preventing drilling fluid loss and that has a reduced tendency to blow around and be lost when added through the mud hopper. Durian peel fibers (waste) used as medium mixed-in a special drilling fluid might solve mixing (before the spot) and lost circulation problem.

1.3 SIGNIFICANCE OF THE PROJECT

The main concern of this project is to study the effectiveness of using the durian peel waste as a fluid loss additive in drilling fluid. Through this project, effective solutions which enable to reduce cost and increase the drilling performance will be achieve.

1.4 OBJECTIVES

By considering the problem statement above, the project aims to:

- To study the effectiveness of using durian peel as LCM additives to prevent the lost circulation problem.
- To find the optimum composition of durian peel fiber that can prevent for effective lost circulation.

1.5 SCOPE OF WORKS

The scope of work for this project is limited to the results and the analyses of the lost circulation material (LCM) derived from durian peel waste for the drilling fluid formulation. Hence, the scope of work within one year period consisted of the literature review which involved the drilling fluid properties and composition, lost circulation problem, and the lost circulation material that was chosen and the properties of drilling fluids that are going to be measured.

The laboratory experiments conducted were to formulate a blend of drilling fluid with fluid loss additive and to compare the properties with the base fluid along with the industrial LCM (nut plug), and to test the efficiency of the blend of durian peel waste for the ability to reduce lost circulation.

CHAPTER 2

LITERATURE REVIEW

2.1 LOST CIRCULATION DEFINITION AND CLASSIFICATION

Lost circulation refers to whole mud that is lost to a formation, that is all or part of the circulating mud fails to return to the surface. (Kate Van Dyke, 200) For this to occur both of the following conditions must exist:

- The drilling fluid overbalances the problem formation
- There is a path that allows the mud to flow into the formation and away from the wellbore.

2.1.1 Formation Type of Losses

Based from the repeated experimental work of the Petroleum Extension Service, University of Texas at Austin (2000), mud cannot be forced into impermeable rocks such as shales or low permeability limestones without fracturing. There have been innumerable cases of lost circulation in wells where no gravels or cavernous beds were exposed in the open hole, and it is clear in these cases that the mud was lost to faulted or fractured zone.

The types of losses can generally be categorized as the followings:

2.1.1.1 Natural Occurring Losses

Naturally occurring losses can be defined as losses resulting from some aspect of the formation being drilled. Losses are common in various formations such as:

- Unconsolidated formations which include sand and gravel.
- Permeable formations such as poorly cemented sandstone.
- Cavernous and vugular formations which include gravel, limestone and dolomite.
- Natural fractures or fissures which can occur at all depths in all formations.

Losses increase in older, harder more consolidated formations with depth. It is common to encounter fractures near faults and areas exposed to tectonic stress. Voids and fractures can generally be recognized by a change in the drilling parameters and when this occurs losses can be expected.

Commonly, when losses occur whilst drilling these formations, they will increase proportionally with depth as more of the formation is exposed. Invariably LCM treatment of some degree, and associated lost time, is required to minimize or cure these losses.

2.1.1.2 Mechanically Induced Losses

Mechanically induced losses can be defined as losses resulting from some aspect directly related to the drilling operation. Losses are caused by over pressuring and fracturing the formation which, once fractured, will easily re-fracture with 1 over pressure. The most common causes of mechanically induced losses are:

- High hydrostatic pressure resulting from an excessive mud weight.
- High hydrostatic pressure resulting from an excessive annular cuttings load.

- High hydrostatic pressure resulting from an excessive Equivalent Circulation Density.
- High surge pressure resulting from an excessive drill string or casing running speed.
- High downhole pressure resulting from a restricted annulus.

Commonly, when losses are induced, they can be minimized or cured by altering the drilling or operational parameters without resort to a lost circulation treatment.

2.1.2 Severity of Losses

Lost circulation occurs in varying degrees and the severity of these losses is an indicator of the mud loss to the formation. It can arbitrarily be classes as below:

Table 1: Classification of loss severity [KMC,2006]

Type of Losses	Dynamic Losses bbl/hr
Seepage losses	< 10
Partial losses	10-30
Severe losses	30-100
Total losses	>100

2.1.2.1 Seepage losses

Seepage losses are arbitrarily defined to as dynamic losses of up to 10 bbl per hour when circulating at the minimum pump rate used for drilling. Static losses are generally not associated with this classification. Commonly, initial seepage losses will be minimal and will increase with drilling as more of the specific formation is exposed. Losses of this severity are commonly encountered in porous sands and fractured formations.

The type of loss, naturally occurring or mechanically induced, can usually be resolved by suspending drilling, circulating the hole clean and observing the losses whilst varying the pump rate and pressure. It is not uncommon for seepage losses to self heal with time as cuttings bridge the pore throats or micro fractures.

2.1.2.2 Partial losses

Partial losses are arbitrarily defined as dynamic losses of 10 – 30 bbl per hour when circulating at the minimum pump rate used for drilling. Static losses are sometimes associated with this classification. Losses of this severity are commonly encountered in unconsolidated formations, vugular carbonates and fractured formations.

The type of loss, naturally occurring or mechanically induced, can usually be resolved by suspending drilling, circulating the hole clean and observing the losses whilst varying the pump rate and pressure.

2.1.2.3 Severe losses

Severe losses are arbitrarily defined as dynamic losses of more than 30 - 100 bbl per hour when circulating at the minimum pump rate used for drilling. Static losses are generally associated with this classification. Commonly, severe losses are instantaneous as fluid is lost to a void, the initial volume lost can range from tens to hundreds of barrels after which the losses may moderate or cease.

Losses of this severity are commonly encountered in vugular carbonates and fractured formations. The type of loss can be assumed to be naturally occurring.

2.1.2.4 Total losses

Total losses are arbitrarily defined as a total absence of returns when circulating at the minimum pump rate used for drilling. Static losses are also very high which necessitates new mud volume with which to maintain a full annulus. Commonly, it is often difficult, if not impossible, to mix new mud volume at the rate required to maintain a full annulus with high static losses, such a situation may result in a well control situation as the mud column and resultant hydrostatic pressure is diminished.
Losses of this severity are commonly encountered in vugular carbonates and fractured formations. The type of loss can assumed to be naturally occurring.

2.2 DRILLING FLUID

The drilling fluid plays several essential functions in drilling wells. If the mud properties (physical, chemical, and rheological) are incorrect, safety and economics may be severely compromised. The drilling fluid is the single most essential system in safe, efficient, and economic oil well drilling. Drilling fluids are a fluid that is used in a drilling operation in which that fluid is circulated or pumped from the surface, down the drill string, through the bit, and back to the surface via the annulus.

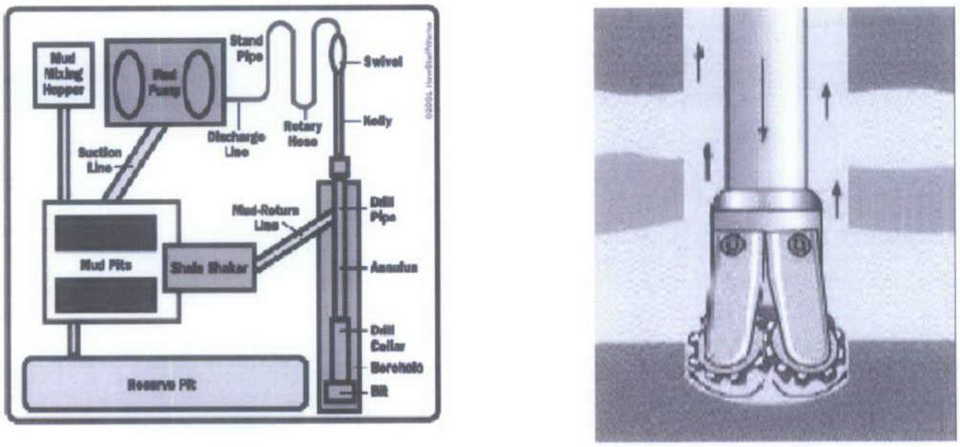


Figure 1: Drilling Fluid

The drilling fluid called mud only looks like mud. Actually, it is a complex mixture of water or oil, clays, and chemicals. Its composition and properties have been carefully studied and tested. Its study is closely associated with chemistry, math, and physics. The term *mud* refers technically to a suspension of solids in water or oil, while *drilling fluid* is a broader term including air, gas, water, and mud. Drilling fluid is the more appropriate term for including all types of fluid used, but mud is preferred in the field for naming the most common type.

Primarily, the functions of a drilling fluid are to:

i. Remove cuttings from wellbore

All cuttings from drill bit must be transported to the surface because if it is not, the drilling efficiency will decrease. Hence, mud must be designed such that it can carry cuttings to surface while circulating and to suspend the cuttings while not circulating.

ii. Cool and lubricate the bit

The rock cutting processes will generate a great deal of heat at the bit so technically it will overheat and quickly wear out, unless the bit is being cooled down. The circulation of the mud will cool the bit down and help lubricate the cutting process.

iii. Protect the wall of the wellbore

The mud has to seal off the permeable formations in order to avoid any damages, hence it will form a thin impermeable mud cake (or filter cake) at the borehole wall. The cake should not be too thick, otherwise, it may cause stuck pipe.

iv. Prevent formation fluids from entering the wellbore

The mud is designed to create an overbalanced drilling condition. Hydrostatic pressure is exerted by the mud column should be slightly higher than the formation pressure because if it is not, an influx of formation fluids into the wellbore will occur. However, if the hydrostatic pressure is too high, it will fracture the formation and causes **lost of circulation.** The mud can sometimes seep through the filter cake and into the formation (filtrate). The lost mud and the filtrate can cause solid deposition and clay hydration in the pore space and will reduce the permeability.

v. Maintain wellbore stability

Borehole stability problems can occur in troublesome formation and the most common problem is shale instability due to pressure differential between borehole and shale pore pressure; and the hydration of the clay within the shale by mud filtrate containing water. Pressure differential can be overcome by controlling the mud weight and the hydration of the clays can be overcome by using non water-based mud or inhibited mud.

2.2.1 Basic Mud Classifications

Drilling fluids can be divided into seven major classifications, depending on the continuous phase fluid and the type and condition of the major additive within the continuous phase. A continuous phase of a drilling fluid is the main component of the system as it is the carrying phase into which everything else is mixed. (Dowell Drilling Fluids Technical Manuals) They are as follows:

i. Fluids with water as the continuous phase and with clays present dispersed throughout the water (*"dispersed water-based mud"*)
ii. Fluids with water as the continuous phase and with clays present inhibited from dispersing throughout the water (*"non-dispersed water-based mud"*)

iii. Clear fluid systems based on water with soluble salts used to control density (*"solids free"* systems or *"brines"*). Brines may include acid soluble solids that can be removed from the reservoir face by circulating acid past the reservoir.

iv. Fluids with oil as the continuous phase and less than 10% water by volume, with any water forming an emulsion of water within the oil (*"oil mud"*)

v. Fluids with oil as the continuous phase and more than 10% water by volume, with the water forming an emulsion of water within the oil (*"invert oil emulsion mud"*)

vi. Fluids with air as the continuous phase (*"air drilling"*)

vii. Water-based systems incorporating air present in gaseous form within a liquid (*"aerated"* and *"foamed"* systems)

2.2.2 Mud physical properties

These properties are important to ensure that the mud quality has not deteriorated and must be regularly measured at the site by the field tests. If one has encountered that the mud quality has been deteriorated; it must be treated in order to function properly. (Steve Devereux)

2.2.2.1 Density

Primary control of downhole pressures is obtained with mud of such density as to exert a greater hydrostatic pressure on the formation than exists within formation pores. The lower safe limit of mud density is calculated by the density to balance the formation of the pore pressure, plus a small additional amount as a safety margin.

2.2.2.2 Fluid loss

The fluid loss property of mud indicates how well the mud forms a seal against permeable formations. High fluid loss mud will build up a thicker, stickier wall cake that is likely to lead to problems such as differential sticking. Ideally the mud should build up a thin, tough, and impermeable cake fairly quickly.

2.2.2.3 Sand Content

Sand is normally the most abrasive solid present in the mud and a high sand content will increase wear on pumps, valves, and other equipments. However, all solids in the mud will contribute to mud abrasiveness. Sand content should be kept as low as possible by using the solids-control equipment properly.

2.2.3 Mud Rheology

Rheological properties measured with a rotational viscometer are commonly used to indicate solids buildups flocculation or deflocculation of solids, lifting and suspension capabilities, and to calculate hydraulics of a drilling fluid (Drilling Fluid Manual). At a given temperature and pressure, fluids are characterized by their behavior under transient conditions, as manifested by their response time to change conditions of flow. The behavior in laminar flow is characterized by their experimental flow curve.

The flow and suspension properties of drilling fluids are usually described with Bingham Plastic (BP) and power-law rheological models.

2.2.3.1 Newtonian Fluids

The shear stress of Newtonian fluids is directly proportional to the shear rate; if one variable is doubled, the other one is doubled also (Rheology Manual, 1982). The rheological equations is

$$\mu = \tau / \gamma$$

Where

μ = viscosity

τ = shear stress

γ = shear rate

The equation is called Newton's Law of viscosity. All gases at ambient temperature and pressure and most simple fluid (like water) exhibits Newtonian behavior (Fluid Facts, 1998). The following plot is obtained in Cartesian coordinates

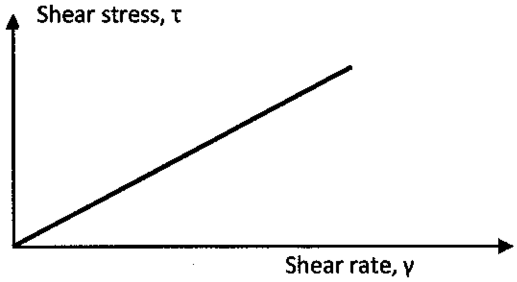


Figure 2: Newtonian Fluids Behavior (Drilling Mud and Slurry Rheology Manual, 1982)

Referring to the figure 2 above, a straight line passing through the origin; the fluid begins to move as soon as a nonzero force is applied.

2.2.3.2 Non-Newtonian Fluids

Non-Newtonian fluids are fluid which has no direct proportionality between shear stress and shear rate, as shown by the figure 3 below.

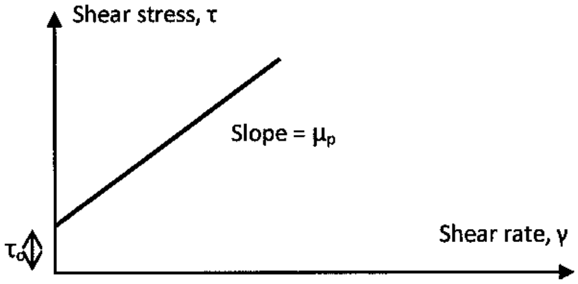


Figure 3: Non-Newtonian Fluids Behavior (Drilling Mud and Slurry Rheology Manual, 1982)

The flow behavior of non-Newtonian fluid is much more complex than Newtonian fluid. For this fluid, the viscosity varies with the shear rate. Most drilling fluid are non-Newtonian and vary considerably in their flow behavior (Fluid Facts, 1998). To be meaningful, a viscosity measurement made on a non-Newtonian must always specify the shear rate. Drilling fluid are shear thinning when they have less viscosity at higher shear rates than at a lower shear rate.

2.2.3.3 Bingham Fluids

In Bingham plastic fluids the shear stress also varies linearly with shear rate but, unlike Newtonian fluids, a minimum force must be applied to impart motion to them. This force is known as the yield-point. Such fluids are characterized by two constants (1) yield point, τ_o which corresponds to the smallest force required to set the fluid in motion (2) plastic viscosity which is the ratio between the increment in the shear stress and the corresponding increment in the shear rate, which is the curve of the slope in figure 2 (Drilling Mud and Slurry Rheology Manual, 1982).

Currently, Bingham Plastic Model is the most widely used mathematical rheology model in the oil fields. Raw data are generated from 600 rpm and 300 rpm readings, which are measured by viscometer.

Plastic viscosity (PV) = 600 rpm reading – 300 rpm reading
Yield point (YP) = 300 reading – PV
(Amoco Production Company Drilling Fluids Manual 1994)

a) Plastic Viscosity (PV)

Plastic viscosity is the part of flow resistance in a mud caused primarily by the friction between the suspended particles and by the viscosity of the continuous liquid phase (Principle of Drilling fluid Control). This parameter is a function of the concentration solids, the size and shape of the solid particles and the viscosity of the liquid phase. It increases with increasing solid content or, for constant solid content, with increasing number of solid particles (fine particles), that is, with increasing specific particle surface. A change in the plastic viscosity of a drilling fluid will cause small changes in yield point, but yield point may be altered with little or no change in plastic viscosity. Plastic viscosity and yield point are absolute flow properties and reflect the colloidal and surface active behavior of solids present in drilling fluid.

b) Yield Point (YP)

The yield-point results from the cohesive forces between the particles, due to electric charges on their surfaces, in other words, it is the initial resistance to flow caused by electrochemical forces between the particles (Aminuddin, 2006). The forces exist between the solid particles and are the results of positive and negative electrical charges located on or near the surface each particle. The magnitude of these forces depend on the type of the solid and their surface charges, the amount of the solid present and the ion concentration in the liquid phase.

c) Gel Strength

The initial, 10 seconds and the 10 minutes gel-strength are an indication of the attractive forces operative in static condition. It can be measured by using the Viscometer. If the differences between these two gel-strengths are large, the gel is known as progressive; if it is practically difference, it is known as flat. It measures of static attractive forces, while the yield point is a measure of dynamic forces.

Excessive gelatin is caused by high solid concentration leading to flocculation. Gelatin should not be allowed to become much higher than is necessary to perform the function of suspension of cuttings and weight material (Aminuddin, 2006)

2.2.4 Mud chemical properties

In addition to apparent and plastic viscosity, yield point, gel strength, filtration, and density, drilling mud has other properties classified as chemical properties. This category includes properties such as pH, alkalinity, calcium content, salt content, and others that affect the performance of drilling mud, either as chemical additives or as contaminants. Chemical properties can have a wide range of effects on drilling mud. Often chemicals are used to treat and fine-tune the mud so that control of other drilling fluid properties can be achieved.

The chemical characteristics of the mud are mostly determined by wellbore stability considerations of the formations drilled through in a particular hole section. In addition, the mud should not damage the reservoir (reduce permeability), or at least damage done to reservoir permeability should be capable of being repaired (by using acid to remove plugging solids) or bypassed (explosive perforations penetrating through the damaged zone).

2.2.5 Composition of Mud

Mud contains:

- Fluid phase – water or oil (in this project it'll be water)
- Solids (to give desired mud properties)
    - Inactive Solids – do not react within mud (e.g. barite, drill cuttings) to give required mud weight
    - Active Solids – clays that react with chemicals (e.g. bentonite, attapulgite clays) cause further viscosity and yield point.
- Additives – aid to control viscosity, yield point, gel strength, fluid loss, pH value, filtration behavior.

2.2.6 Mud Additives

The control of drilling fluids always presents two problems

i. Determining what properties (weight, viscosity, gel strength, filtration, etc)
ii. Selecting the type of mud and the materials and chemicals that will produce the desired mud properties at the lowest cost.

The properties of drilling muds can be adjusted to meet any reasonable set of conditions to overcome the lost circulation problem. While other additives in mud include the corrosion inhibitors, emulsifiers, flocculants, shale control inhibitors and surfactants, these four additives are the major ones that clearly needed to clarify:

2.2.6.1 Viscosity Control Additives

It is used to control the viscosity of the mud and is being graded according to their yield points. Examples of viscosifiers are Bentonite and Polymers, while thinners are such as Phosphates and Lignites.

2.2.6.2 Fluid Loss Control Agents

Fluid loss control agents are used to control the fluid loss to permeable zones to create an ideal filter cake. Bentonite is one example of effective fluid loss control agent while starch, polyacrylates and lignite are the other examples.

2.2.6.3 Weighting Agents

These are agents to control the mud density and Barite is the primary weighting material used while others can be Hematite and even Calcium Carbonate.

2.2.6.4 pH control

pH control is needed to keep pH of mud high (between 9.5 – 10.5) to prevent corrosion and hydrogen embrittlement. Caustic soda is one of the major additives used.

2.3 LOST CIRCULATION MATERIALS

According to Offshore Mineral Management Glossary, lost circulation material (LCM) is defined as a substance added to cement slurries or drilling mud to prevent the loss of cement or mud to the formation. The substance may contain a blend of granular, fibrous and flake material with particle size distribution believed to be large enough to form bridge of material in the fracture or cavern. It is important that the bridge be within the formation and not on the surface of the wellbore where it can be dislodged by the drill pipe.

The commercially available LCM products vary from a wide variety of materials. Particle shapes are granular, flake or fibrous at sizes denoted as fine (typically 20 – 60 mesh), medium (16 – 60 mesh) and coarse (16 – 30 mesh).

- *Fibrous LCM* – Shredded sugar cane stalks (bagasse), cotton fibers, hoghair, wood fibers, sawdust, and paper pulp.
- *Flaky materials* – Shredded cellophane, mica flakes, plastic laminate and wood chips.
- *Granular materials* – Ground nutshells, calcium carbonate, sized salt, hard rubber, asphalt, gilsonite and plastic.
- *Slurries* – Hydraulic cement, diesel oil-bentonite-mud mixes, and high-filter-loss muds.

2.3.1 Nut Plug as the industrialized Lost Circulation Material

Nut plug cellulose is ground walnut or pecan hulls. It is used for the treatment of lost circulation. Nut plug material is available in fine, medium, and coarse particle sizes, and may be used in all types and densities of fluid systems. Nut plug material may be used as a granular-type lubricant to reduce torque and drag.

Table 2: Physical and Chemical Characteristics of a Nut Plug [Anchor Drilling Fluids USA, Inc]

PHYSICAL / CHEMICAL CHARACTERISTICS			
Boiling Point °F:	N/A	Appearance:	Gray to Black
Specific Gravity:	2.20 – 2.35	Odor:	None
Vapor Pressure:	N/A	Form:	Solid – Granular
Percent Volatility:	N/A	pH:	4.5 – 6.0
Solubility in Water:	Insoluble	Particle Sizes:	500 m – 4mm

Nut plug cellulose is an effective lost circulation treating material and has been used widely in the drilling applications. It has a granular shape, and can be used in a blend of various sizes (fine, medium, and coarse) to prevent lost circulation or regain returns once losses begin. Nut plug hulls are available in two types of material and that is pecan and walnut. The walnut hulls however have the greater strength. As for the treating levels, it depends on the severity of the losses and type of formation where the losses occur.

Nut plug material may be mixed with other shaped materials to provide a wide variation for optimum control. Nut plug also is used to treat the entire system or added as a concentrated pill and can be added to other special slurries, such as high fluid loss squeezes, to assist in forming strong bridging plugs. Typical treating levels for preventative measures are from 2 to 5 lb/bbl (5.7 to 14.2 kg/m^3), and for more severe losses use 5 to 25 lb/bbl (14.2 to 71.3 kg/m^3). The main reason on why nut plug is an effective lost circulation treating material is because it has a high compressive strength, and can be used, if desired, as a lubricant.

The advantages on using nut plug as the LCM in drilling applications is:

i. Inert additive, compatible in all types and densities of fluids
ii. Will not fement
iii. Unaffected by pH or temperature
iv. Based on particle shape, size and compressive strength, it is a superior lost circulation additive

2.3.2 Durian peel fiber as a Lost Circulation Material

The **durian**, is the fruit of trees from the genus *Durio* belonging to the Malvaceae, a large family which includes hibiscus, okra, cotton, mallows, and linden trees. Widely known and revered in Southeast Asia as the "King of Fruits", the fruit is distinctive for its large size, unique odor, and formidable thorn-covered husk.

Figure 4: Durian

The results of dried durian peel or through its scientific name, *Durio zibethinus,* and dried durian fiber chemical analysis performed following TAPPI standards are shown in Table 3. It can be seen that chemical compositions of dried durian peel and dried durian peel fiber are not much different as shown in Table 3 (S.Charoenvai, 2005). Dried durian peel and dried durian peel fiber have lignin and hemicelluloses. The primary cause of the change in the characteristics of the natural fibers in composite is due to the chemical decomposition of the lignin and the hemicelluloses. The alkaline pore water in the composite dissolves the lignin and hemicelluloses and thus breaks the link between the individual fiber cells.

Table 3: Chemical Composition of Durian peel and durian fiber

Chemical Composition	Dried Durian Peel [%]	Dried Durian Peel Fiber [%]	Standard
Ash content	5.5	4.3	TAPPI-T2211-om-93
Alcohol-benzene solubility	13.4	11.5	TAPPI-T204-om-93
Lignin	10.9	10.7	TAPPI-T222-om-98
Holocellulose	47.1	54.2	Acid Chlorite's Browning
Alpha cellulose	31.6	35.6	TAPPI-T203-cm-88
Hemicellulose	15.5	18.6	

CHAPTER 3

METHODOLOGY

3.1 PROJECT FLOW CHART

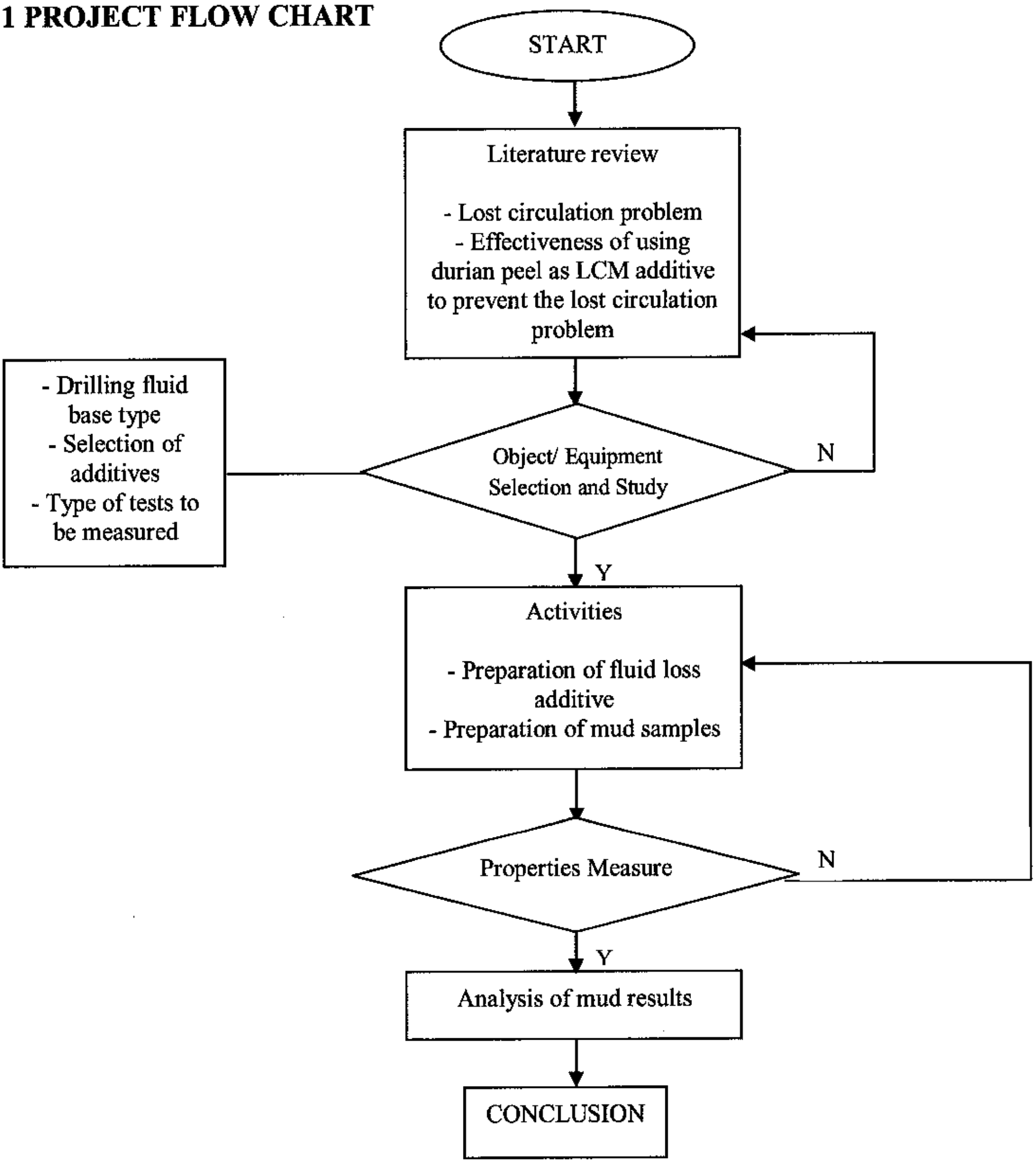


Figure 5: Project Flow Chart

3.2 PROJECT GANTT CHART

In order to complete the tasks within the given time, it is crucial to plan wisely all through the semester to get a successful result. The planned schedule for this semester 2 is as in Figure X below:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project work continues (Rheological data)	▨	▨	▨											
Submission of Progress Report 1				●										
Project work continues				▨	▨	▨	▨							
Submission of Progress Report 2								●						
Seminar								▨						
Project work continues (Continuation on rheological data)								▨	▨	▨	▨			
Poster Exhibition										●				
Submission of Dissertation (soft bound)													●	
Oral Presentation													●	
Submission of Dissertation (hard bound)														●

Figure 6: Project Gantt Chart

3.3 PREPARATION OF ADDITIVES

The durian peel additive was prepared by first collecting the durian peel and let it dried naturally over the heat of the sun. After the drying process, it was typically being cut into smaller pieces, so it would be easier to grind and blend for further use.

Next, the additive was put into the dehumidifying process for 24 hours at 120°C in an oven. A Mortar Grinder is then being used next to grind the additives into smaller particles. In order to obtain the desired size, which is the 150 microns, 212 microns and 300 microns, a Sieve Shaker (as shown in Figure 8) will be used.

Figure 7: Durian peel fiber in 150 microns

Figure 8: Sieve Shaker

The reason on why the selected sizes were being chose (150 microns to 300 microns) is because it is the best recommended particle sizes as mentioned in API 13B-1.

Table 4: Definition of particle sizes

Particle Size	Particle Classification
Greater than 200 microns	Coarse
200 - 250 microns	Intermediate
250 - 74 microns	Medium
74 - 44 microns	Fine
44 – 2 microns	Ultra Fine
2 – 0 microns	Colloidal

Source: API Bul. 13C (June 1974), American Petroleum Institute, Dallas [16]

3.4 DRILLING MUD PROPERTIES

1. A suspension of 75 μm bentonite powder is prepared by adding 22.5 ± 0.01 g of bentonite to 350 ± 5 cm3 deionized water while stirring.

Figure 9: 22.5 ± 0.01 g of bentonite powder

Figure 10: Stirring in the MultiMixer

2. After stirring for five ± 0.5 minutes, the container is removed from the mixer and its side is scraped with the spatula to dislodge any bentonite adhering to the container

walls. All bentonite clinging to the spatula are being assured to incorporate into the suspension.

3. The container is then replaced and continued to stir. The container may need to be removed from the mixer and the sides scraped to dislodge any bentonite clinging to container walls after another 5 and 10 minutes therefore total stirring time is equal to 20 ± 1 minute.

3.5 MUD DENSITY TEST

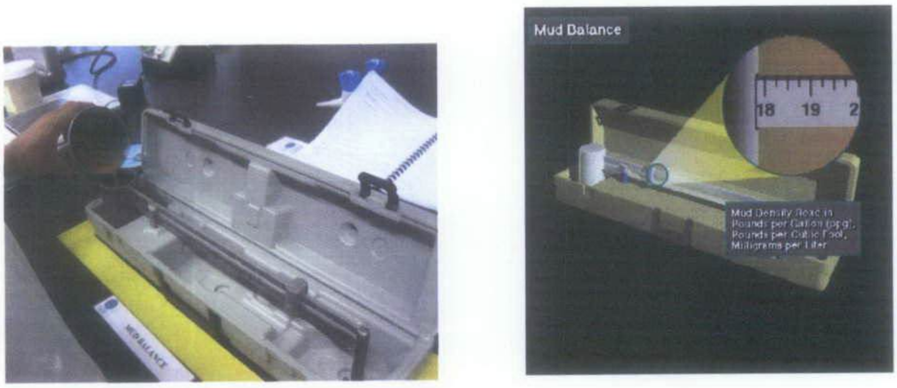


Figure 11: Mud balance

Mud density is commonly measured with a mud balance capable of ± 0.1 lb/gal accuracy.

1. The mud balance base is placed on a flat, level surface.

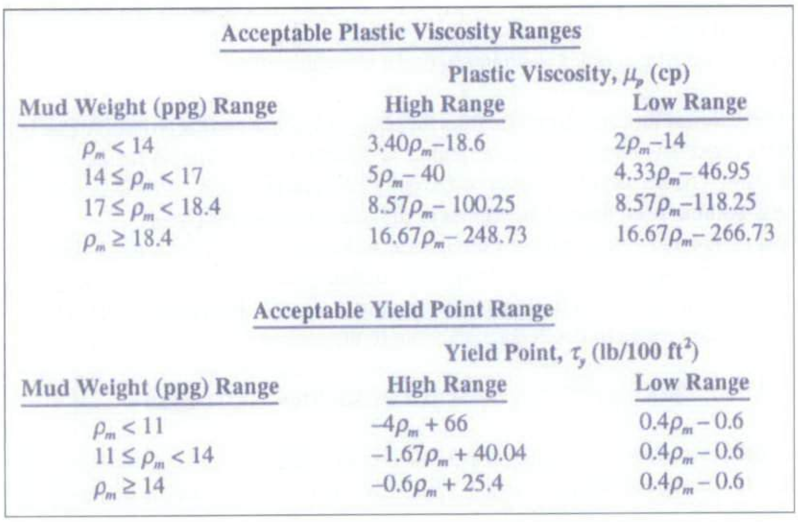
2. The clean and dry mud balance cup is filled with the sample of mud to be tested. The cap is rotated until it is firmly seated. Some mud is ensured to expel through the hole in the cap to remove any trapped air or gas.

3. The thumb is placed over hole in cap and the cap is held firmly on the cup. The outside of the cup is washed or wiped until dry.

4. The balance arm is then placed on the support base and balanced it by moving the rider along the graduated scale until the level bubble is centered under the center line.

5. The density (weight) of the mud shown is read at the left hand edge of the rider and report to nearest 0.1 lb/gal.

3.6 RHEOLOGY TEST



Acceptable Plastic Viscosity Ranges

Mud Weight (ppg) Range	Plastic Viscosity, μ_p (cp) High Range	Plastic Viscosity, μ_p (cp) Low Range
$\rho_m < 14$	$3.40\rho_m - 18.6$	$2\rho_m - 14$
$14 \le \rho_m < 17$	$5\rho_m - 40$	$4.33\rho_m - 46.95$
$17 \le \rho_m < 18.4$	$8.57\rho_m - 100.25$	$8.57\rho_m - 118.25$
$\rho_m \ge 18.4$	$16.67\rho_m - 248.73$	$16.67\rho_m - 266.73$

Acceptable Yield Point Range

Mud Weight (ppg) Range	Yield Point, τ_y (lb/100 ft^2) High Range	Yield Point, τ_y (lb/100 ft^2) Low Range
$\rho_m < 11$	$-4\rho_m + 66$	$0.4\rho_m - 0.6$
$11 \le \rho_m < 14$	$-1.67\rho_m + 40.04$	$0.4\rho_m - 0.6$
$\rho_m \ge 14$	$-0.6\rho_m + 25.4$	$0.4\rho_m - 0.6$

Figure 12: Limits of plastic viscosity & Yield Point

The raw and beneficiated bentonite samples have undergo a series of testing to determine its capability as a drilling mud material in accordance to the standard requirements of API 13B Section 4 specifications (API Specification 13B, 1995). The acceptable plastic viscosity and yield point ranges are as in Figure 12.

1. A prepared drilling mud sample is placed inside the cup and immersed the rotor sleeve exactly to the scribed line of Fann VG Rheometer as shown in Figure 13.


Figure 13: Fann VG Rheometer

2. With the sleeve rotating at 600 rpm, the dial reading is waited to reach a steady value and is being recorded.

4. 300 rpm is then shifted and the dial reading is waited to reach steady value and is being recorded too.

5. Next, the drilling mud sample is stirred for 10 second at the high speed (600 rpm).

6. The mud is allowed to still undisturbed for 10 seconds, then the hand wheel is turned slowly and steadily in the direction to produce a positive dial reading. The maximum reading is the initial gel strength. The initial gel strength (10 seconds gel) is recorded in lb/100 ft2 (Pa). Then, the drilling mud sample is re-stirred for measurement of 10 minutes gel strength.

7. Plastic viscosity and yield point can be calculated by using the following equations:

Plastic Viscosity, cP = [600 rpm reading] – [300 rpm reading] (4.13)
Yield Point, lb/100 ft2 = [300 rpm reading] – Plastic Viscosity (4.14)
YP/PV ratio = Yield point ÷ Plastic viscosity (4.15)

3.7 FILTRATE VOLUME PERFORMANCE TEST

1. The bentonite suspension as prepared before is collected and tested in section and stirred in the container for 1 ± 0.5 minute.

2. The suspension is poured into the filter press cell to within about ½ inch (13mm) of the top of the cell. The assembly of the filter press cell is completed. The filter cell is then placed in the frame and the relief valve is closed. A container will be placed under the drain tube.

3. The first timer is set for .5 ± 0.1 minutes and the second timer for 30 ± 0.1 minutes. Both timers would be started and pressure on cell should be adjusted at 100 ± 5 psi (690 ± 35 kPa). Both of these steps shall be completed in less than 15 seconds. Pressure shall be supplied by compressed nitrogen.

4. At 7.5 ± 0.1 minutes, on the first time, the container is removed and any adhering liquid on the drain tube would be discarded. Then, the dry 10-cm3 graduated cylinder is placed under the drain tube and continued collecting filtrate to the end of the second timer set at 30 minutes. The graduated cylinder is then removed and the volume of filtrate collected (Vc) is recorded.

5. The filtrate volume of the bentonite suspension is calculated as:

Filtrate vol., cm3 = 2 x Vc

Figure 14: Low Pressure Low Temperature Filtration Test

CHAPTER 4
RESULTS & DISCUSSION

4.1 BASE SAMPLE

The base sample is set for the purpose of comparison before the usage of additives in the mud formulation. The purposes of using bentonite in the formulation are to increase hole cleaning capability, reduce water seepage or filtration into permeable formations, to form a thin filter cake of low permeability and to avoid overcome loss circulations (Darley H.C.H & Gray G.R, 1983).

The experiments were conducted in accordance with the standard stipulated in API RP 13B-1; Recommended Practice Standard Procedure for Field Testing Water-Based Drilling Fluids. Sample 1 actually is the base case for this experiment. Other drilling mud samples were prepared in order to measure the change in properties such as density, plastic viscosity, yield point, gel strength and filtration loss as compared to the base case. Three different particles size of durian peels which are 150 µm, 212 µm and 300 µm were used in these experiments.

4.2 COMPOSITION AND PROPERTIES OF DRILLING FLUID TESTED

The experiments were conducted according to the standard which has stipulated in American Petroleum Institute - API 13B-1; *'Recommended Practice Standard Procedure for Testing Water-Based Drilling Fluid'*. In the experiment, the mud was mixed with additives as suggested by the API 13B-1 such as bentonite, and any changes

Table 7: Properties of drilling fluid tested for 212 microns of durian peel

	Base Sample	**212 microns**					
Amount, (g)	0	5	10	15	20	25	30
Density, (lbs/gal)	8.6	8.7	8.7	8.8	8.9	8.9	9.0
VG 600 rpm, (lb/100ft^2)	16	24	34	36	39	37	37
VG 300 rpm, (lb/100ft^2)	10	17	26	27	29	28	28
Plastic Viscosity (cP)	6	7	8	9	10	9	9
Yield Point, (lb/100ft^2)	4	10	18	18	19	19	19
Gel Strength – 10sec	18	15	15	14	12	11	10
Gel Strength – 10min	22	18	17	16	14	13	11
Filtration rate, (ml/min)	0.58	0.35	0.31	0.28	0.26	0.25	0..24
Mud Cake Thickness, (mm)	2.21	2.06	2.20	2.46	2.56	2.71	2.83

Table 8: Properties of drilling fluid tested for 300 microns of durian peel

	Base Sample	**300 microns**					
Amount, (g)	0	5	10	15	20	25	30
Density, (lbs/gal)	8.6	8.7	8.9	8.9	9.0	9.1	9.1
VG 600 rpm, (lb/100ft^2)	16	27	40	40	40	38	35
VG 300 rpm, (lb/100ft^2)	10	20	32	33	33	32	30
Plastic Viscosity (cP)	6	7	8	7	7	6	5
Yield Point, (lb/100ft^2)	4	13	24	26	26	26	25
Gel Strength – 10sec	18	13	13	12	11	10	8
Gel Strength – 10min	22	18	15	15	14	12	10
Filtration rate, (ml/min)	0.58	0.43	0.38	0.34	0.32	0.29	0.27
Mud Cake Thickness, (mm)	2.21	2.40	2.47	2.54	2.67	2.81	2.94

4.3 MUD WEIGHT

In the experiment, the mud weight intentionally set around 8 ppg, so that any changes can be observed easily. In field, the amount of mud weight is around 8 to 11 ppg. The mud maybe unnecessarily heavy and the additional weight may cause lost returns to the balance between full circulation and loss is often close (Aminuddin, 2006). The balance between full circulation and loss is often close. Control of the weight must be between narrow limits, often only 0.1 or 0.2 ppg of the total weight. The mud weight must be sufficient to confine the formation fluid but not great enough to break it down. Regardless of the weight required, the weight of the mud, along with the pit level and salt content, should be checked at regular intervals.

Many types of minerals have been used as a medium of weighting agent, such as barite, iron oxide and calcium carbonate. However, it has been identified, component such as barium which is present in barite, mercury and cadmium which is from barite impurities as the sources of pollution to the environment (Darley H.C.H & Gray G.R, 1983). The cost of barite alone may comprise one-half to two-third of the mud bill of operations in areas where abnormal pressure are encounters (Rogers, 1978).

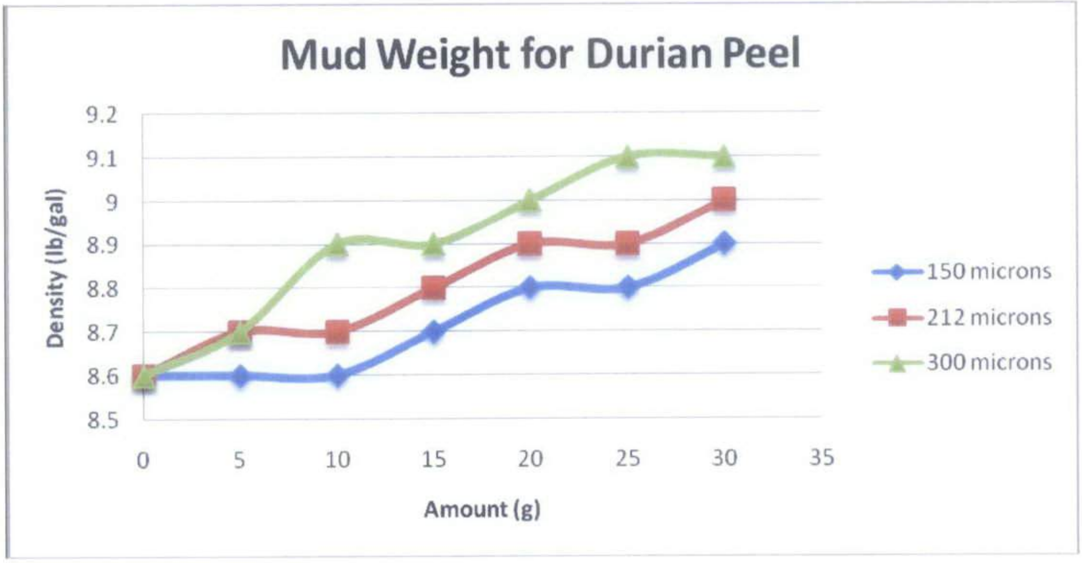


Figure 15: Mud weight for Durian Peel

From the samples obtained and achieved, the graph illustrates that as the amount of additives is added increasing, the mud weight of the formation increased as well. As for the size of 150 microns increased independently, for sizes 212 microns and 300 microns, they had the same weight until the amount of 5g. For any further addition of the additive, it caused the curves to be diverged. For the 300 microns of particle size, the increment is quite large and this might due to the solid content as the size is larger compared to the other two sizes.

Density is the most important mud property affecting penetration rate. For any given formation pressure, the higher the density, the greater will be the differential pressure (Darley H.C.H & Gray G.R, 1983).

4.4 PLASTIC VISCOSITY

Viscosity ('thickness') is the term that describes resistance to flow. High viscosity liquids are relatively immobile when subjected to shear (a force applied to make them move), whereas low viscosity fluids flow relatively easily. Measurement of viscosity, and other rheological properties, can be made using either capillary or rotational rheometers, the choice of system depending on the properties of the material being tested and the data required.

Figure 16 below illustrates that for each of the sizes, the trend is almost to a linear straight graph as it increased as the amount of additive increased. The viscosity keeps on increasing until 10g for 300 microns, 20g for 212 microns and 25g for 150 microns. As the amounts of additives were continually added, the curves however started to decrease. Hence we can say that further increment of additives will caused the plastic viscosity to decrease and the samples had already reached its optimum values.

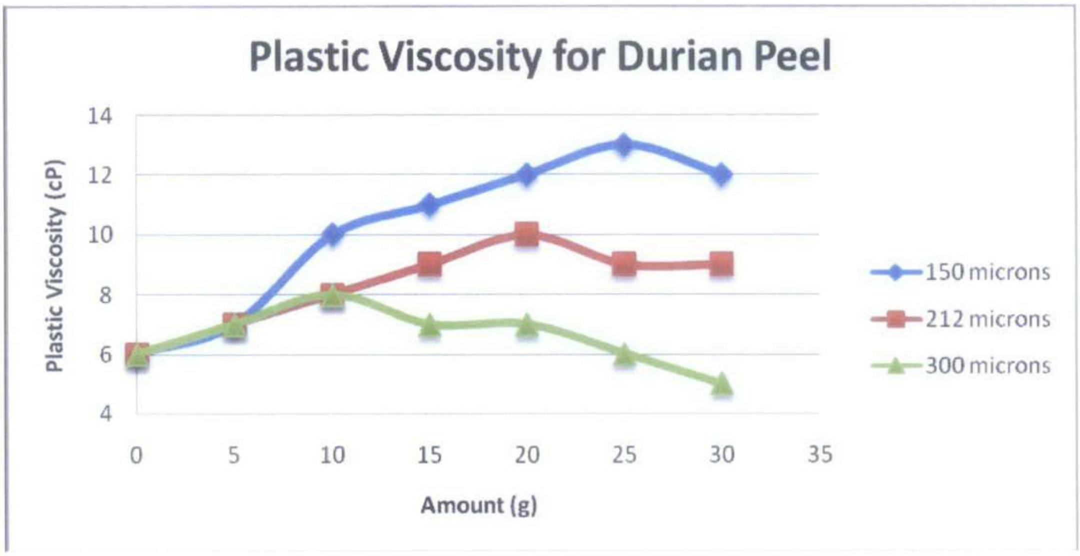


Figure 16: Plastic Viscosity for Durian Peel

Optimum value can be found when there is a change in the trend of the curve from the graph. Optimum value is the best possible value for the formulation to work affectively. For 150 microns, the optimum value is around 25g; for 212 microns, the optimum value is around 20g; and for 300 microns, the optimum value is around 10g.

As expected, 150 microns shows a slightly higher value of plastic viscosity compared to 212 microns and 300 microns due to its particle size. The viscosity tends to be greater with smaller particles. [Jamie Fletcher, 2008]

4.5 YIELD POINT

The attractive force of the particles; between clay particles and to a lesser extent by friction between the particles is the yield point. A change in plastic viscosity of drilling mud will cause small changes in yield point (Aminuddin, 2006). The magnitude of these forces will depend on the type of their solid present, the ion concentration in the liquid phase (Growcock F 2005).

High yield point may be due from the concentration by salt which increase in solid content with consequent decrease in inter particle distance and insufficient concentration of the thinning agent. Thinning agent is used to neutralize the attractive forces (Growcock, 2006).

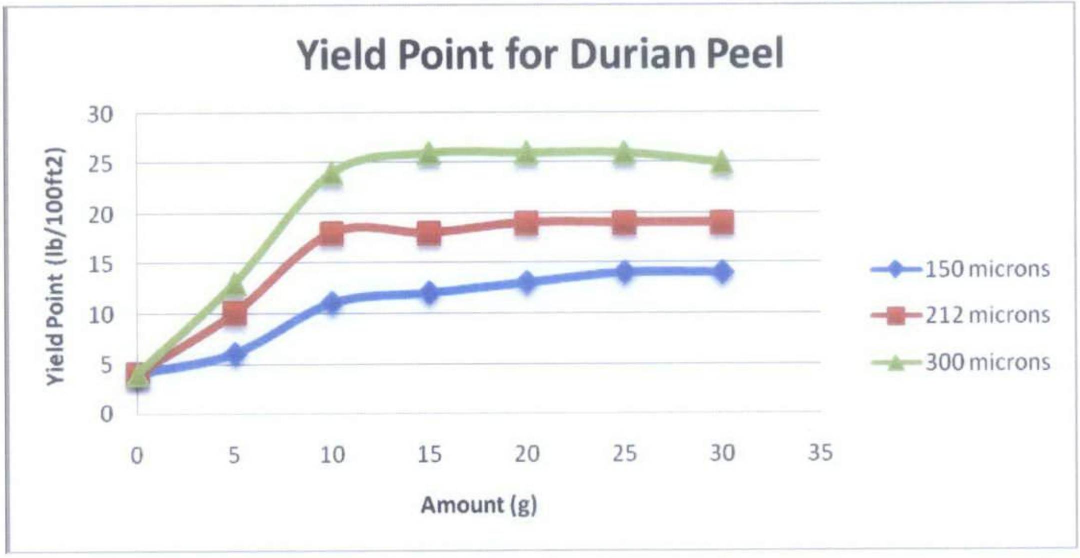


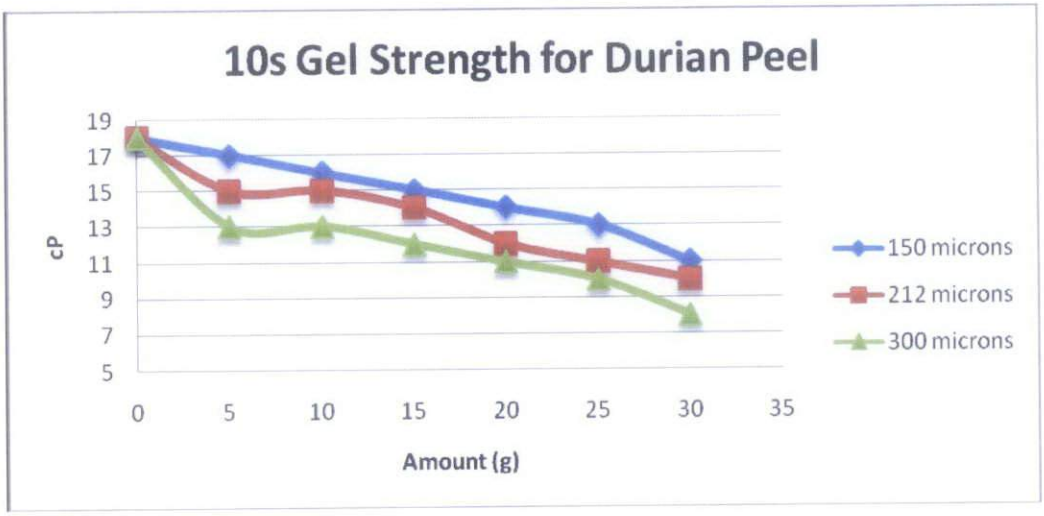
Figure 17: Yield Point for Durian Peel

From Figure 17 above, for all three sizes, the value of yield point increases as the amount of additives increased. The trend of the curves meets the original definition of yield point at which the material begins to deform plastically. Prior to the yield point the material deformed elastically and will return to its original shape when the applied stress is removed. Once the yield point is passed some fraction of the deformation will be permanent and non-reversible. For all the three sizes, they began to be permanent at around 10g.

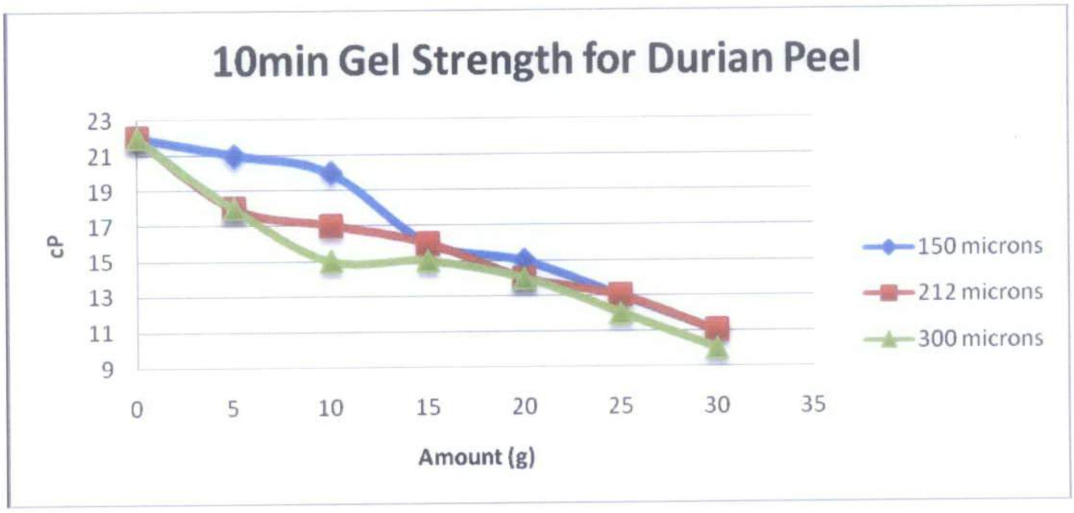
For 150 microns, it reached its yield strength or the elastic limit at around 11 $lb/100ft^2$ and its ultimate strength at around 14 $lb/100ft^2$. For 212 microns, the yield strength or the elastic limit is achieved around 18 $lb/100ft^2$ and reached its ultimate strength at around 19 $lb/100ft^2$. And the yield strength or elastic limit for 300 microns is achieved approximately at 26 $lb/100ft^2$ and its ultimate strength at 25 $lb/100ft^2$.

4.6 GEL STRENGTH

Gel strength, 10 seconds and 10 minutes indicate the strength of attractive forces (gelation) in drilling fluid under static condition. Excessive gelation is caused by high solids concentration leading to flocculation (Drilling Fluid Manual, Amoco Company). The 10 minutes gel strength will cause the higher gel strength as the particles have more time to arrange themselves in a proper manner in which the repulsive and attractive forces best satisfied (Rogers, 1978)



(a)



(b)

Figure 18 (a) & 18 (b): 10 seconds and 10 minutes Gel Strength for Durian Peel

As both the graph shown, they illustrate that the values obtained tend to decrease as the amount is increased. In general, high gel strengths are not desirable and can even be dangerous. The drilling crew can get an idea of the gel strength of the mud –whether it is low, medium, or high from the way the mud flows and stiffens in the ditches and mud pits [Routine Drilling Operations].

Gel strength denotes the thixotropic properties of the mud. Basically it indicates the pressure required to initiate flow after the mud has been static for some time and the suspension properties of the mud and hence its ability to suspend cuttings when the mud is stationary. Gels are described as progressive/strong or fragile/weak. For a drilling fluid, the fragile gel is more desirable.

4.7 FILTRATES

Filtrates are the liquid part of the mud. When the mud is forced against a permeable zone, the solids in the mud will form a plaster or "wall cake" against the formation face. Some of the liquid fraction will filter through this cake and into the formation. This liquid fraction (water plus dissolved salts) is the filtrate.

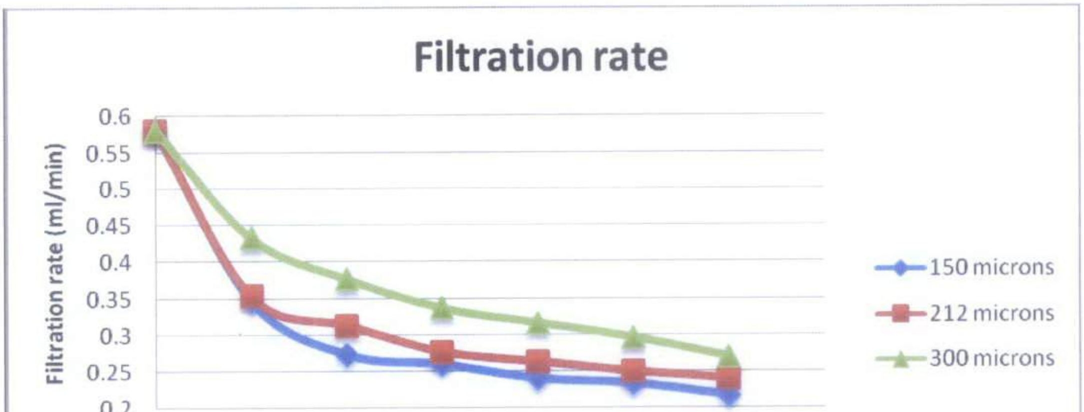


Figure 19: Filtration rate of Durian Peel

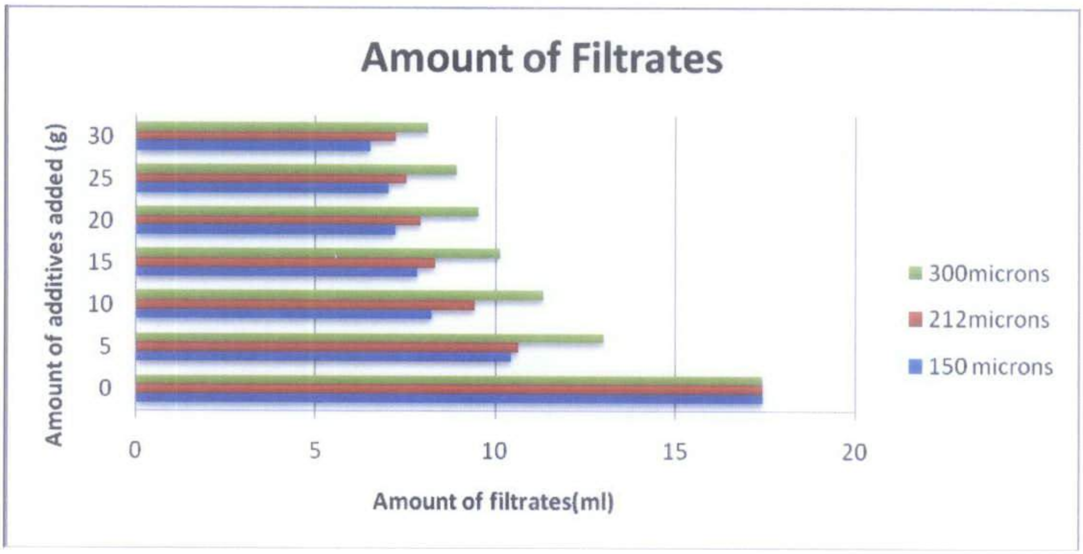


Figure 20: Amount of filtrates

Figure 19 & Figure 20 above illustrate that the amount of water filtered is decreasing as the amount of additives is increasing. This proves the fact that as the amount of additives is increasing, the viscosity increased too, causing the water to be less filtered. Hence, we can conclude that the higher the viscosity of the mud, the better the mud formulation is.

4.8 MUD THICKNESS

Water is continuously lost from drilling mud to permeable formations during drilling operations. A permeable formation, such as sand, operates as a strainer, holding back the solids in the mud while permitting the water to pass into pore space. These solids are deposited on the face of the sand in the form of filter cake. No cake is formed on impermeable shale, but its surface is wetted by the water of the drilling mud. Although this wetting is not well understood, it does take place and may cause sloughing and caving.

Figure 21: Mud cake

Figure 22 below illustrates that as the amount of additives were added gradually to the mud formulation, the mud cake's thickness will be increasing gradually too, due to the increasing of its' densities. Note that for 212 and 300 microns, as they were first decreased a bit then only started to increase, and this might be of some human errors done while doing the experiments. But for 150 microns, the trend behaves better than the 212 microns and 300 microns. It obeys the concept of as the more the amount of the durian peel is added gradually, the weight of the mud is increased causing the density and plastic viscosity to increase while the yield point and gel strength to decrease. This affects the rate of the water filtered to decrease, causing the thickness of the mud cake to increase too as well.

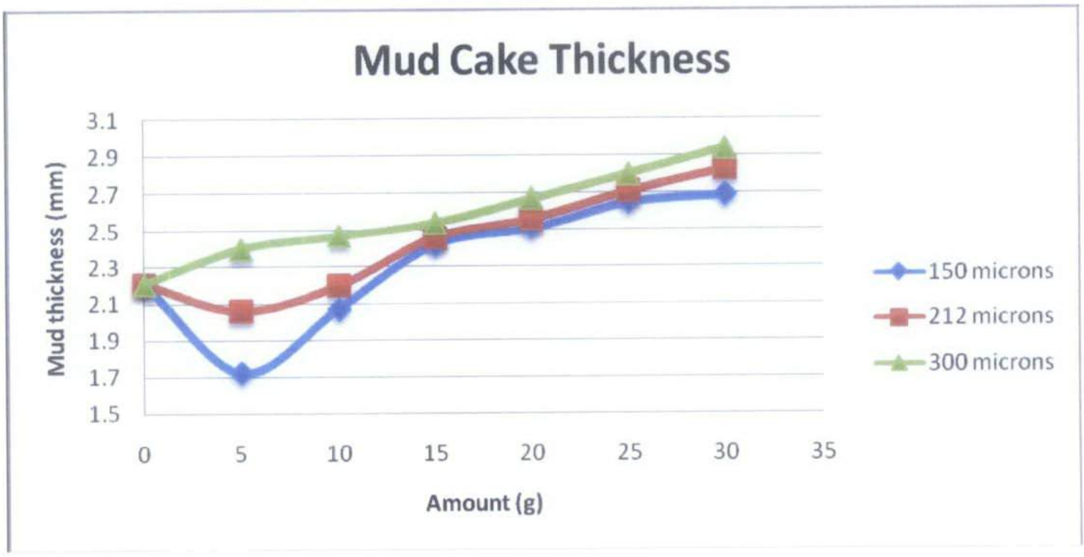


Figure 22: Mud cake Thickness

CHAPTER 5

CONCLUSION

The functioning of a drilling mud is directly related to its density, viscosity, gel strength, and filtration characteristics. In order for the performance of drilling fluid to be controlled, it must be carefully made up and treated during drilling. Proper treatment of mud can affect any one of its properties, but, because the properties are often related, treatment will often affect several, if not all, of the properties.

Durian peel was chosen to be the additive tested in this project because of the fact that Malaysia is one of the biggest producer and exporter of durian. Apart of its effectiveness in cost and availability, considering that it is a waste also means that it is an environmentally friendly additive, hence it is sensible to choose these durian peel fibers to be tested for a better drilling fluid formulation.

The parameters for evaluation during the experiments were particle sizes and amount of additives added. The selected sizes of additives were 150 microns, 212 microns, and 300 microns; and the amount that were gradually added were between 5g to 30g.

Overall, the results show that as the amount of additives is increased, the density, plastic viscosity, and yield point increased as well. Meanwhile, the gel strength and the filtration rate show a reverse relationship with the added amount and went decreased as the amounts of additives were added progressively. Hence, the particle sizes did affected and has a direct relationship with properties measured.

The optimum value for the best concentration is obtained at the amount of 25g at the 150 microns size of durian peel with the concentration of 71.43 kg/m^3.

Comparing it with the other additives tested as done in the past experiments, the optimum value obtained for corn cobs is at 9.5g at the size of 125 microns and have a concentration of 9.43 lb/bbl. For sugar cane, the optimum value obtained is at 6.5g at the size of 125 microns and have a concentration of 6.45 lb/bbl. In actual situation, taking the actual industrial LCM for the comparison, Nut Plug uses 5.7 to 14.2 kg/m^3 with the size of 500 microns to 4mm.

Hence, this means that durian peel is not that effective enough to be the best lost circulation material because the amount needed is higher and since it is one of the weak fibered material, it does not have the more high compressive strength.

Other factors such as the species of the durian, human errors done in the experiments, and some chemical reactions that were left in the equipments before might as well affected the overall results to its performance.

CHAPTER 6

RECOMMENDATIONS

For future work, more works are needed to investigate the best formulation of the additives. The particle size of the additives should be varied from 1 to 300 microns. The amount use should be tested from the minimum, so that a proper graph will be obtained.

More tests should be conducted to get an accurate result such as High Temperature High Pressure test, dynamic filtration test, formation damage system test, X-Ray fluorescence test, and solid-liquid content test. These tests should be able to justify, identify and investigate further the properties of the fluid.

The chemical analysis of the fluid should also be tested and this category includes other drilling mud properties such as pH, alkalinity, calcium content, salt content, and others that affect the performance of the drilling mud, either as chemical additives or as contaminants.

Economic evaluation should also be conducted to compare the effectiveness of the formulations to be used in the industry. Also, the usage of oil as the base fluid maybe an option to cope with different types of drilling fluids programs, and to compare the effectiveness between the water-based and the oil-based drilling fluids.

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