CERTIFICATION OF APPROVAL

RHEOLOGICAL STUDY OF JATROPHA CURCAS OIL AS OBM IN DRILLING OPERATION AND FORMATION DAMAGE CONTROL.

by

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Approved by,

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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.

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ABSTRACT

The drilling fluid industry has long been plagued with environmental issues, given that the trend of drilling practices seem to be favoring Synthetic Based Mud, which uses mineral oil as the base fluid. The side affects are obvious, given that the usage of non-biodegradable oil that is pumped into the subsurface leads to a significant amount of fluid invasion into the formation. The need therefore arises for a mud system that utilizes biodegradable oil, from renewable sources that can match the rheological properties of the conventionally used mud systems, whilst also leaving a minimal impact on the formation permeability (formation damage).

The ester derived from Jatropha Oil was reported to have similar properties to diesel oil. Hence, given that it is a source of biodiesel that can be renewed (derived from the Jatropha Curcas Plant), the prospect of developing new systemts based on this oil is enticing especially in environmentally protected areas. The idea of having drilling fluid that causes little or no damage to the formation whilst being environmentally stable is one that this paper intends to put forth. This research is focused on achieving industry acceptable rheological specifications for the ester based mud system and comparing it to mineral based systems. Formation damage properties were also measured to indicate the extent of its permeability affects.

ACKNOWLEDGEMENT

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CHAPTER 1

INTRODUCTION

Common Base Oil in the Market

The increase in petroleum oil prices and environmental concerns has driven the increase in oil prices worldwide. This is a cause for concern particularly in the drilling fluid industry where almost 80% of drilling fluid used and developed is mostly oil based mud, where the common base fluid used is either diesel or mineral oil. This two materials account for nearly 50% of the cost of the drilling fluid itself. Due to environmental concerns and the increasing price of petroleum, the demand for biodiesel has increased.

Jatropha oil, being poisonous in nature, cannot be used for nutritional purposes without detoxification, and this makes its use as energy/fuel source very attractive.
According to the European Journal of Scientific Research,

The oil extracts exhibited good physicochemical properties and could be useful as biodiesel feedstock and industrial application. (A. Emil et. al)

Due in part to the gradual depletion of world petroleum reserves and the impact of environmental pollution of increasing exhaust emissions, there is an urgent need to develop alternative energy resources, such as biodiesel fuel. Vegetable oil is a promising alternative mainly because it is renewable, environmentally friendly and can be produced easily. This makes its use as base oil in drilling fluids all the more attractive.

Synthetic drilling fluid uses synthetic oil (minimal or no aromatic compounds) as its base fluid. In this project, the properties of Jatropha Curcas are to be measured and characterized in its use as substitute base oil. The formation damage extent will also be determined through experiments to be conducted.

Problems Statement

In order to develop a reliable, environmentally friendly, economical alternative to mineral oil, the rheological properties of Jathropa Curcas oil in an oil based mud will be compared and contrasted against Sarapar 147 (Linear Parrafin-Synthetic) and Saraline (both mineral oil) at a standard condition of 90°F.In order to quantitatively measure its effect, complete rheological tests have to be done on the formulations at a standard temperature of 90°F.

To estimate the effects of Jatropha Curcas oil against mineral based oil used in a synthetic mud on formation damage using a standardized core sample and testing procedures.

Objective

The objectives of the project are:

a) To develop a formulation for Drilling Fluid using Jathropa Curcas oil as the base oil in Synthetic Based Mud with acceptable Rheological and Fluid Loss properties.
b) To compare and contrast rheological behavior of Jatropha Curcas Oil against Mineral Based Oil, ie Sarapar 147 and Saraline
c) To estimate the effects of formation damage control using Jathropa Curcas based drilling.

1.4 Methodology

The project is conducted on an experimental basis. The mud formulation will be prepared in the lab, for 3 different samples, each with a similar amount of additives added (additives that help give viscosity, fluid loss control, loss circulation material, and alkalinity and brine salinity percent). A complete mud check will be done on the mud formulations to evaluate it in terms of fluid loss control, rheological behavior, temperature stability and formation damage control. To evaluate the formation damage control, a core sample will be prepared, preferably of the Berea Sandstone variety, and each core will be subjected to the different formulations, at constant differential pressure, ideally at a 90 degree angle (vertical), and the damage ratios will be compared to gauge the effects of Jatropha based oil. Jatropha oil will have to undergo an esterification process first to remove impurities and ensure it is suitable to be used as a base fluid. The short life span of the oil (before it degrades) means that experimentation will have to be conducted within a week after the purifying process of the oil. Sarapar and Saraline will be purchased from SHELL and it can be used directly as the base oil. Then, result will be obtained, tabulated and analyzed. Conclusion and recommendation will be made for future improvements. Detailed methodology flow chart and description are highlighted in Chapter 3 Methodology.

1.5 Scope of Study and Feasibility within Time Frame

The scope of study mainly investigates the rheological properties of the ester based SBM, and its behavior, with contrasts provided against mineral oil. The study will be divided into two stages; the first stage involves researching the basic properties of the Jathropa Curcas oil and determining an ideal formulation to be developed. Research will also be conducted on mineral oil to gain an understanding of the fundamental differences. The second stage will focus on experimental work in the lab, using the three base fluids with particular attention given to the characteristics of Jathropa Curcas oil and its rheological behavior. Experiments will also be focused on the formation damage control of Jathropa Curcas SBM, with contrast provided against Sarapar 147 and Saraline. A limited amount of formulations will be prepared, in order to fit within the time frame, hence proper research must be done into the formulation calculations beforehand. Result collected from experiments will be analyzed and discussed.

CHAPTER 2

THEORY & LITERATURE REVIEW

2.1 Theory

(a) Jathropa Curcas Oil as Base Oil

Jatropha curcas is a species of flowering plant in the spurge family, Euphorbiaceae, that is native to the American tropics, most likely Mexico and Central America. It is cultivated in tropical and subtropical regions around the world, becoming naturalized in some areas.

Since Jathropa Oil cannot be used for nutritional purposes without proper detoxification, its use as a base oil for drilling fluid is all the more appealing. The ester derived from Jatropha oil, known as fatty acid methyl ester (FAME), was reported to have similar physical and chemical properties with those of diesel oils. This paper aims to formulate a new ester-based mud using Jatropha esters. Other commonly used base fluids and examples are as follows:

- Oils – Diesel
- Low Toxic Mineral Oil Base Fluids – LTOM – Escaid 110
- Synthetic Base Fluids
    - IO Internal Olefin $C_{16} – C_{18}$
    - LAO Linear Alpha Olefin
    - IP Iso Paraffin
    - LP Linear Paraffin
    - ESTER Palm Oil / Olefin etc
    - Blends of Ester & Synthetic (for deepwater)

Currently, the common base oils used to build oil base mud are low toxicity mineral oil (ie Sarapar 147 and Saraline). It is basically a refined mineral oil with its intrinsic toxicity reduced by the removal of aromatic compounds, both mono and polynuclear aromatics.

well. While much of this paper refers to SBMs as a general class of materials, it is important to recognize that SBMs are not a uniform product.

(c) Rheological behavior

Drilling fluids are designed specifically to suit each well that is going to be drilled. The engineering design of drilling fluids takes into account all the mud properties to produce mud with the desired functions. The main properties of drilling fluids are:

- Mud Density
- Rheology
- Shear rate and stress
- Fluid Loss
- Inhibition
- Solids Content

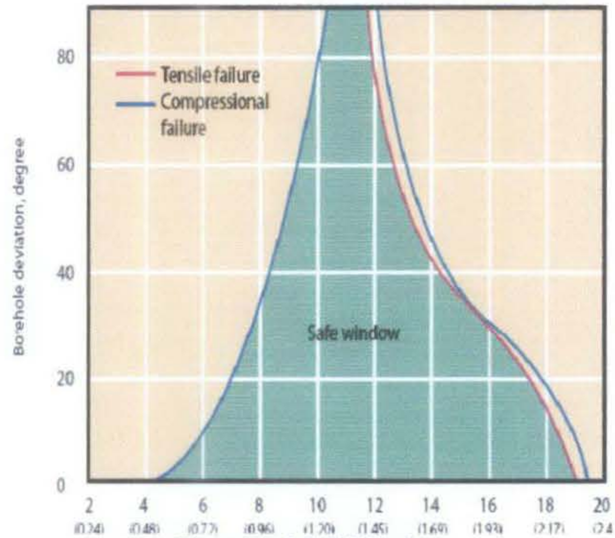


Figure 1: Mud Window

2.1.1 Drilling Fluid

In a basic oil and gas drilling operation, there are 7 basic criteria's that need to be taken into consideration. The drilling fluids design and selection is at the heart of all operations. In drilling operations, the primary objective is to drill and complete wells that will produce oil/gas efficiently.

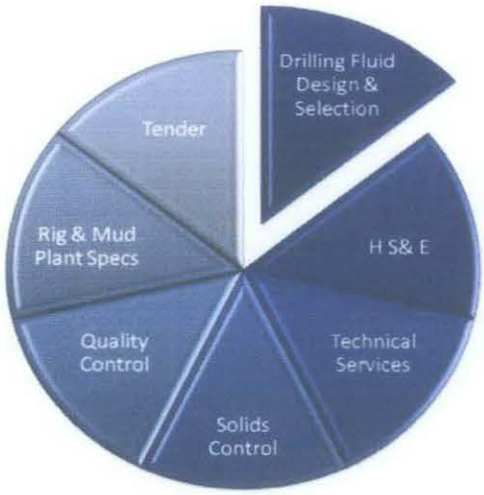


Figure 2: Aspects to Drilling Fluid

There are various aspects to a drilling fluid, each serving a specific function. The different compositions used in a mud aid the production and removal of cuttings from the borehole.

In a rig, the responsibility lies with the mud engineer to constantly monitor and ensure the mud properties are always within specification. He will also recommend good drilling practices to ensure drilling objectives are met.

The choices of drilling fluid should take into account the following:

- Suitability of the formation to be drilled
    - Inhibition
    - Rheology
    - Fluid Loss
    - Temperature Limitation
- Cost
- Environmental Concerns
- Safety
- Availability
- Storage

2.1.2 Factors Affecting Drilling Fluids Selection

- Application interval is important as different mud weights are used at different sections to ensure a slightly overbalance of pressure is always maintained between the formation and the mud column.
  - Drilling surface interval
  - Drilling intermediate interval
  - Drilling production interval
    - Completion method (open hole, cased hole)
    - Production type
- Geology of the formation has to be known prior to drilling so that the mud can be designed to accommodate the varying required inhibition levels according to the porosity of the shale. The following information is needed:
  - Shale type
  - Sand Type
    - Permeability
  - Other formation types
    - Carbonate
    - Salts
- The Make-Up Water of the mud is important so that the brine salinity level can be adjusted accordingly.
  - Type of water
  - Chloride concentration
  - Hardness (calcium/Magnesium concentration of the water)
- Drilling data is vital as the drilling mud is designed to operate at specific conditions. Information such as depth, temperature, angle and mud weight is required beforehand so that the mud can be formulated to perform efficiently at that particular set of conditions.

  - Water Depth
  - Hole Angle

- Drilling Rate
- Maximum Temperature
- Hole Size
- Torque/Drag
- Mud Weight

- Potential problems that may or may not occur during drilling operations have to be accounted for.
    - Shale problems
    - Stuck pipe circulation
    - Depleted sands
    - Bit Balling
    - Fluid loss
- The capacity of the rig and drilling equipments to operate and hold various drilling fluid equipments has to be determined in order to avoid problems like limited surface capacity to hold mud shakers or even locations that are remote and difficult to access.

A properly designed mud is able to

- ✓ Reach geological objective/ target depth at lowest overall cost
- ✓ Enhance penetration rates of the drillbit
- ✓ Reduce hole problems while drilling
- ✓ Minimize formation damage

2.1.3 Mud Density

Mud density, or more commonly mud weight, is the column of mud that replaces the rock that is drilled. The mud column provides bore pressure support to the walls of the wellbore. In most cases, mud pressure (Pm) should be higher that formation pressure (Pf) to prevent the walls from caving in and formation fluids from entering into the wellbore causing a kick or a blowout.

The first critical step towards designing a drilling fluid is to establish the mud weight required to provide the correct level of bore pressure support. Common practice in determining the suitable mud weight is based on the predicted formation pore pressure gradient plus an additional pressure of 200 to 500 psi, so that in constantly remains within the equivalent circulating density of the formation (ECD)- within the stable window.

Mud pressure column should not be lower than the pore pressure gradient to avoid hole erosion, cave-ins, under/overgauged hole and sloughing of the well wall. However, if the mud weight is too high, propagation of formation fracture will be initiated. This can lead tot mud losses and formation damage. Therefore one of the key elements to successfully drilling a stable, near gauge wellbore depends upon planning the correct mud weight overbalance.

2.1.4 Rheology

Rheology is the science of deformation and flow of matter. By making certain measurements on a fluid, it is possible to determine how that fluid will flow under a variety of conditions, including temperature, pressure and shear.

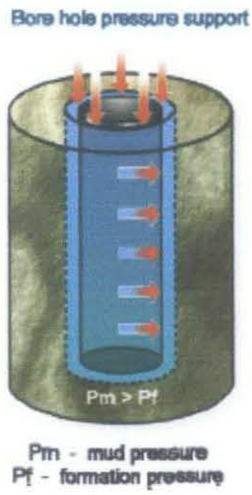


Figure 3: Mud Pressure and Formation Pressure

2.1.5 Viscosity

Viscosity is the substance's resistance to flow and is required in addition to flow rate for hole cleaning.

Viscosity = shear stress (flow pressure)/ shear rate (flow rate)

2.1.6 Shear Rate and Shear Stress

Shear rate is the velocity variation with distance while shear stress is defined as a stress which is applied parallel or tangential to a face of a material, as opposed to a normal stress which is applied perpendicularly. Higher shear rates causes greater resistive force (shear stress). In normal drilling activity, shear stresses in the drill string (where higher shear rate exist) exceed those in the annulus (where lower shear rates exist).

2.1.7 Plastic Viscosity

Friction is fluid is caused by solids concentration, size and shape of solid & viscosity of the fluid phase. PV is usually regarded as a guide to solids control. PV increases when the volume of solids increases or when the size of particle decreases.

2.1.8 Yield Point

Yield Point is the initial resistance to flow caused by electrochemical forces between the particles. This is due to charges on the surface of the particles dispersed in fluid phase. Thus, yield point is dependent upon the surface properties of the mud solids, the volume concentration of the solids and the ionic environment of the liquid surrounding the solids. The high viscosity resulting from high yield point is caused by introduction of soluble contaminant (ions) such as salt, cement, anhydrite or gypsum which interacts with the negative charges on the clay particles. Yield point can be treated with proper chemical treatment.

2.1.9 Gel Strength

The gel strength (10 second gel and 10 minute gel) indicate the attractive force (gellation) in drilling fluid under static conditions. Progressive gels indicate increase in gellation over a period, Excessive gellation can cause problems by swabbing, surging, difficulty getting logging tools to the bottom, retaining of entrapped air or gas in the mud and retaining of sand and cuttings while drilling.

2.1.10 Fluid Loss (Filtration)

Fluid loss is an indication of the amount of water lost from the formation (the passage of filtrate into the formation due to the differential pressure), the solids in the mud usually forms as a filter cake which prevents excessive fluid loss. Desired mud cake properties are :

- Thin and low friction coefficient
- Low permeability

2.1.11 Inhibition

Clay has a tendency of swelling when it comes into contact with water and this causes wellbore stability problems. An inhibitive mud tends to retard or prevent the appreciable hydration or dispersion of formation clays and shales by chemical and physical means.

2.1.12 Solids Content

All mud contains solids (weighting agent, bridging agents, clays, polymers). In addition to that, drill cuttings and fine solids builds up periodically in the mud when drilling. Solids in mud can be determined by its plastic viscosity. The higher the PV is the more solids are in the mud.

2.2 Literature Review

Usage of ester based mud is already beginning to take off. For example, extended reach wells drilled from the Goodwyn Alpha platform have been drilled with a variety of invert-emulsion mud systems. Historically, mud system selection for these wells was based on compliance to environmental regulations and satisfaction of technical criteria. In order to take a more proactive approach to mud system selection and to raise environmental standards to new levels, an initiative was undertaken to replace the environmentally acceptable, and technically competent mud system being used on Goodwyn with a new ester-based system. Ester-based mud systems are considered the “system of-choice” in terms of environmental acceptability and possess inherent lubricating qualities for torque and drag reduction. (E. Daniel et. al, 2000)

Early SBM were made from ester, acetal, ether or polyalphaolefin (PAO) base fluids, followed by internal olefins (IO), linear alpha olefins (LAO) or normal paraffins. Several types of LTOBM, as well as paraffin and olefinbased SBM, were used in drilling the first 13 wells from the Goodwyn Alpha platform, and proved to be both technically competent and environmentally acceptable. A qualitative study was made of the environmental impact of a number of alternative muds/cuttings management options, including total containment, cuttings injection and the use of water or ester based muds. Australian regulatory authorities, in line with North Sea equivalents, viewed EBM as a step change improvement on previous systems. In light of the regulatory authority's preference towards EBM, and Woodside's environmental policy, the decision was made to change from a high-performance olefin to an EBM. Additional considerations were:

·Improved economics of EBM (lower cost ester)

·Woodside found it difficult to justify the economics, risks and associated contingency planning for cuttings injection on Goodwyn, given the lack of cuttings injection experience in the area The risks involved in replacing a technically competent, and environmentally acceptable mud system on these highly aggressive ERD wells were not trivial. It was felt that these risks could be mitigated by developing a new EBM tailored to the wells drilled on the Goodwyn platform.

The first step in the development phase of a new ester based mud is selection of an ester possessing technical qualities similar to those of an olefin-based SBM, with the added environmental qualities. Esters are normally chosen based on the following characteristics:

· Environmental compliance

· Kinematic viscosity

· Elastomer compatibility

· Lubricity

· Alkaline and temperature stability (E. Daniel et. al, 2000)

High biodegradability and relatively low toxicity have long made esters universally recognized as the best base fluids for synthetic-based mud in regards to environmental performance. A major limiting factor in the use of ester-based fluids, particularly in deep water, is the inherently high kinematic viscosity, a condition that is magnified in the cold temperatures encountered in deepwater risers. These higher viscosities are believed to be especially critical in deepwater wells where lack of overburden causes a severely narrowed window between pore pressures and fracture gradients. Other implications of these higher viscosities include limitations on oil/water ratios, mud weights, and drill solids tolerance. (Kim Burrows et al, 2001)

All types of esters, including Jatropha FAME, are relatively stable under neutral condition, but may undergo hydrolysis and revert back to the acid and alcohol in the presence of reserve alkalinity (lime) at temperature exceeding 200°F. A study found that in the presence of 3 to 4 lb/bbl lime, esters hydrolyzed severely during heat aging, which was confirmed by the presence of alcohol byproducts in the muds after being subjected to hot roller. (Kania.D, 2011)

Formation damage can be caused by either a simple or complex process involving any of the phases of producing oil and gas. The dynamics of drilling alone is so great that this process is capable of altering adversely the rock's ability to flow fluids. Formation damage is attributed primarily from two main sources, namely particles plugging and filtrate invasion from drilling fluids. Therefore, to prevent permeability damage effectively, the damage mechanisms should be identified in the first place. The damaging solids may come directly from the fluid system or the formation itself. Invasion of drilling fluid solids into the formation during drilling can eventually cause permeability impairment and thus reduction in well productivity. This is due to the particles plugging in pore spaces, which in turn causes an obstruction for the oil droplets from moving around the wellbore. Particles plugging is most severe at the wellbore face. (Issham Ismail, Jagdeve Babu,2004)

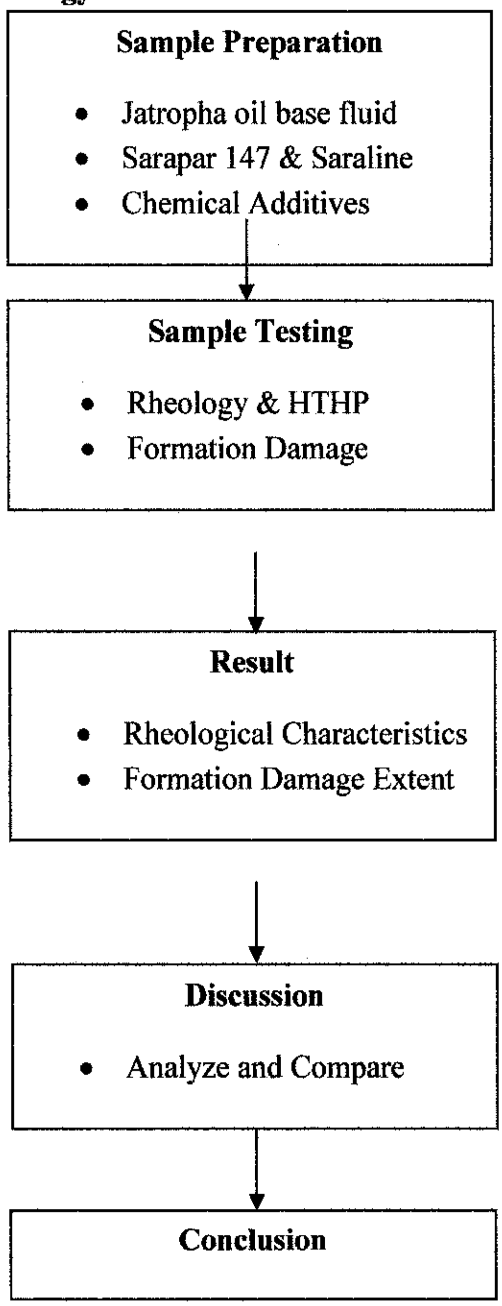
CHAPTER 3

METHODOLOGY

3.1 Activities Gantt Chart

Activities	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
FYP 2 Briefing														
Project Commences														
FAME Preparation														
Base Oil Procurement						1/9/10								
Additive Procurement														
Lab Work(SCOMI)														
Progress Report Submission								16/4/11						
Pre EDX, Poster and Final Report Draft Submission									4/4/11					
EDX											11/4/11			
Final Oral Presentation													20/4/11	
Harbound Submission														4/5/11

3.2 Research Methodology Flow-Chart



3.3 Detailed Descriptions

3.3.1 Basic Properties

Table 2: Basic Properties of Base Oils

	Jatropha FAME	Saraline	Sarapar
Specific gravity	0.87	0.78	0.78
Viscosity @40˚C, cST	5.5	3	2.5
Flash point, ˚C	>85	122	135
Pour point, ˚C	3	12	2

3.3.2 Formulation, Mixing Time and Order.

Table 3: Mud Formulation on function, mixing time and order.

No	Product	Function	SG	Mix 1 lab bbl on Hamilton Mixer		
				Order	Speed	Time, min
1	FAME/ SARAPAR & SARALINE	Base Oil	0.87/ 0.77	1		
2	KXP 019	HT Emulsifier	0.95	2	High	2
3	CONFI TROL F	Liquid Fluid Loss Additive	0.98	3	High	2
4	CONFI-GEL HT	Organophilic Clay	1.60	4	High	2
5	CONFI-TROL 450	Fluid Loss Additive	1.30	6	High	2
6	CONFI-TROL HT	Polymeric Fluid Loss	1.03	7	High	2
7	LIME	Alkalinity	2.30	8	High	2
8	Drillwater	Brine	1.229	9	High	5
9	Calcium Chloride				High	
10	DRILL-BAR	Weighing Agent	4.28	10	High	**

*Total mixing time is 60 minutes.

** Barite is added last, and mixed till 60 minutes.

1) 5 Formulations with varying base oils are mixed using the Hamilton mixer at high speed.

2) As soon as mixing is done, the following tests are done on the mud:

- Rheological properties at 120°F and 150 °F
- Electrical Stability Test at 120°F

3) The mud is stirred until homogeneous and poured into an aging cell,

4) The cell is then pressurized at 100 psi using nitrogen gas, given a shake and purged to remove all oxygen.

5) The cell is re-pressurized at 100 psi, sealed and checked for leaks before being placed in a 250°F preheated over and hot rolled for 16 hours.

6) After 16 hours, the ovens are turned off, oven door is opened wide and the cells are cooled with the help of a fan whilst still rolling in the oven.

7) After 30 minutes, the cells are removed and partially submerged in a water bath for another 30 minutes. Once it is cool and safe enough to be handled, the cells are depressurized and the content poured into a mud cup.

8) The mud is then mixed for 5 minutes using Hamilton mixer at high speed, before the following tests are done:

- Rheological properties at 120°F and 150 °F
- Electrical Stability Test at 120 °F
- HTHP Filtrate Test at 250 °F with 500psi differential pressure
- Mud Cake Thickness

3.4 Materials and Equipments

3.4.1 Materials

There are several materials needed to conduct the experiment in order to investigate the effect of high pressure high temperature to the synthetic drilling mud. The materials needed are jatropha oil as the base fluid for the drilling mud, barite as weighing agent, bentonite as clay component, emulsifier, and chemical additives to ensure the stability of the synthetic drilling mud.

Jatropha oil is extracted from the jatropha plant, it will be purchased from the jatropha extraction plant. Due to its high viscosity, jatropha oil viscosity needs to be reduced by apply cracking process onto the oil to produce less viscosity oil for synthetic drilling mud base fluid. Chemical composition needs to be obtained as well to ensure jatropha oil able to produce miscible synthetic fluid.

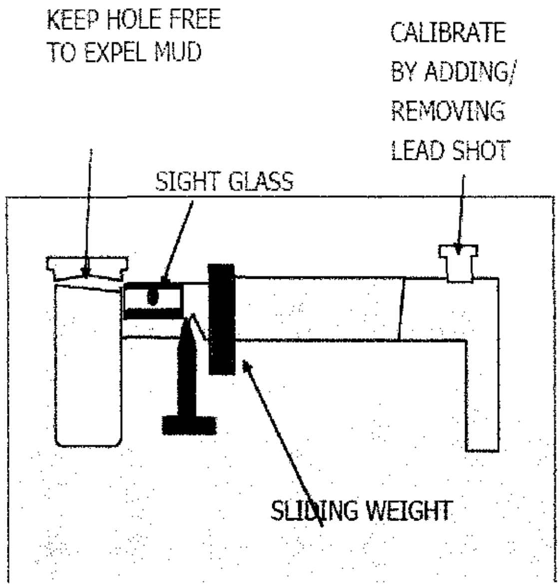
3.4.2 Equipments and Mud tests

Basic properties that will be measured for the drilling fluid are:

- Density
- Rheology
- Fluid Loss
- Inhibition

3.4.3 Density

- Density is by convention called the mud weight
- Units are lb/gal or g/cc,
- Correct and frequent measurement is essential
- Two types of balance
  - Pressurized
  - Non pressurized



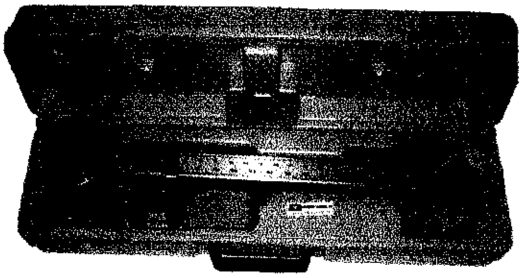


Figure 4: Mud Balance Equipment

3.4.4 Rheology

i) Rheology is tested using the Fann 35.

The Fann 35: Measure viscosity of mud

- Speed : 600,300,200,100,6 and 3 rpm
- Plastic Viscosity (PV) & Yield Point (YP)
  PV = 600rpm – 300rpm
  YP = 300rpm – PV
- Determine 10 seconds and 10 minutes gel
  - Suspension at static condition
  - Progressive/Non-Progressive gel

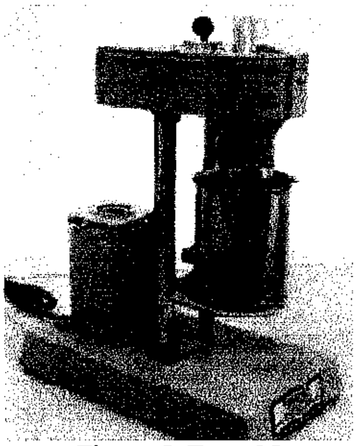


Figure 5: Fann 35

Figure 6 HTHP Filtrate Loss

ii) High Temperature High Pressure Filtrate Loss equipment will be run to determine the filtrate losses under a differential pressure of 500. Pressure applied is positive downwards, so gravity affects the results, but it is usually negligible.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Initial Formulation

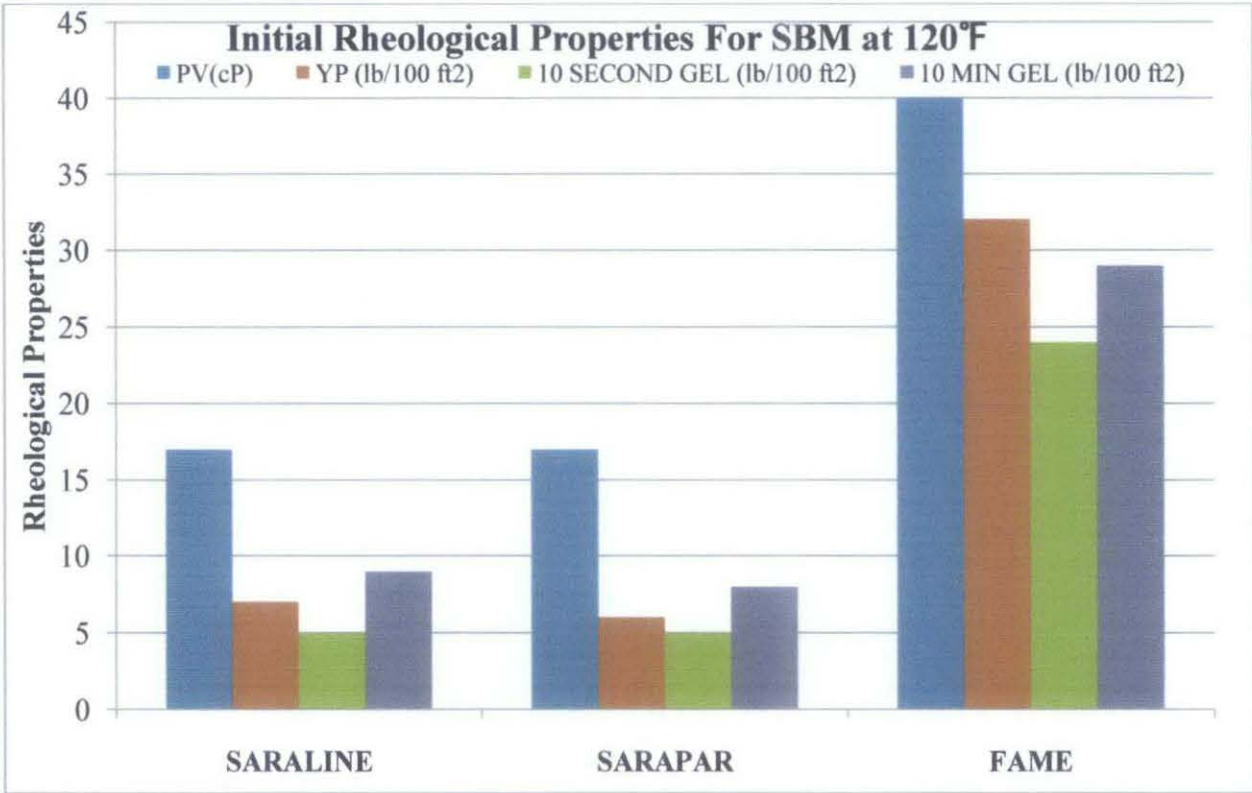


Figure 7: Initial Rheology for First Base Oil Comparative Test

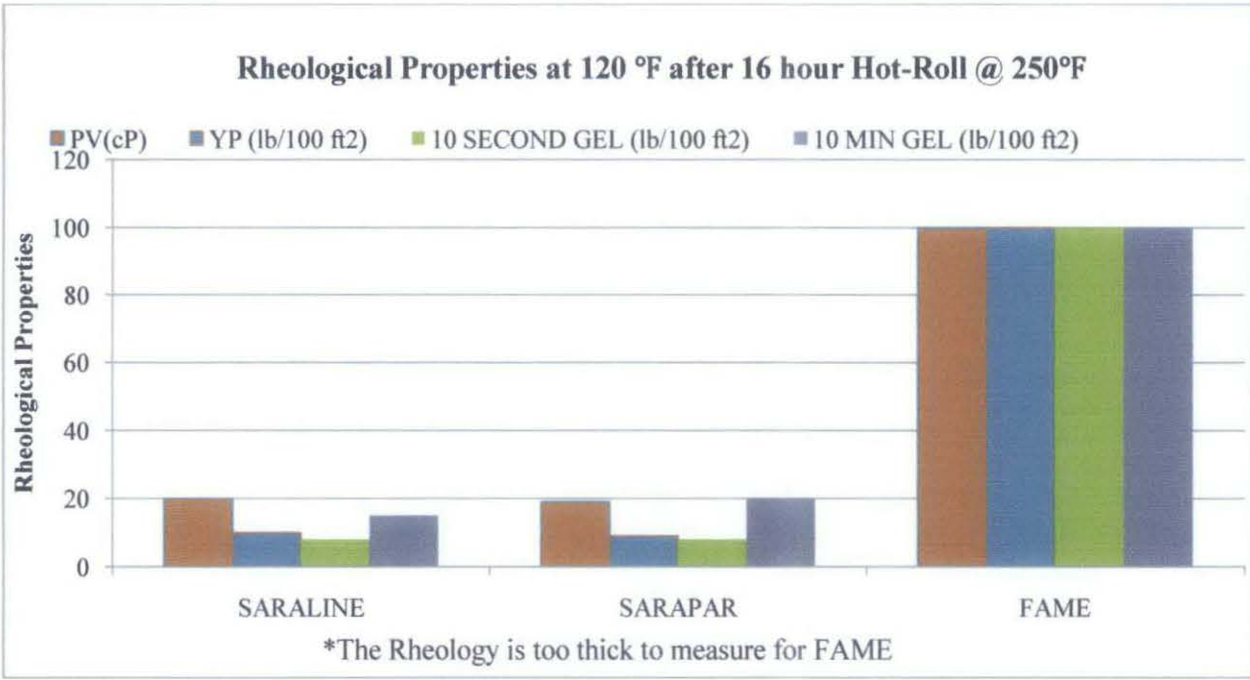


Figure 8: Rheological Properties after 16 hour Hot-Roll for First Base Oil Comparative Test

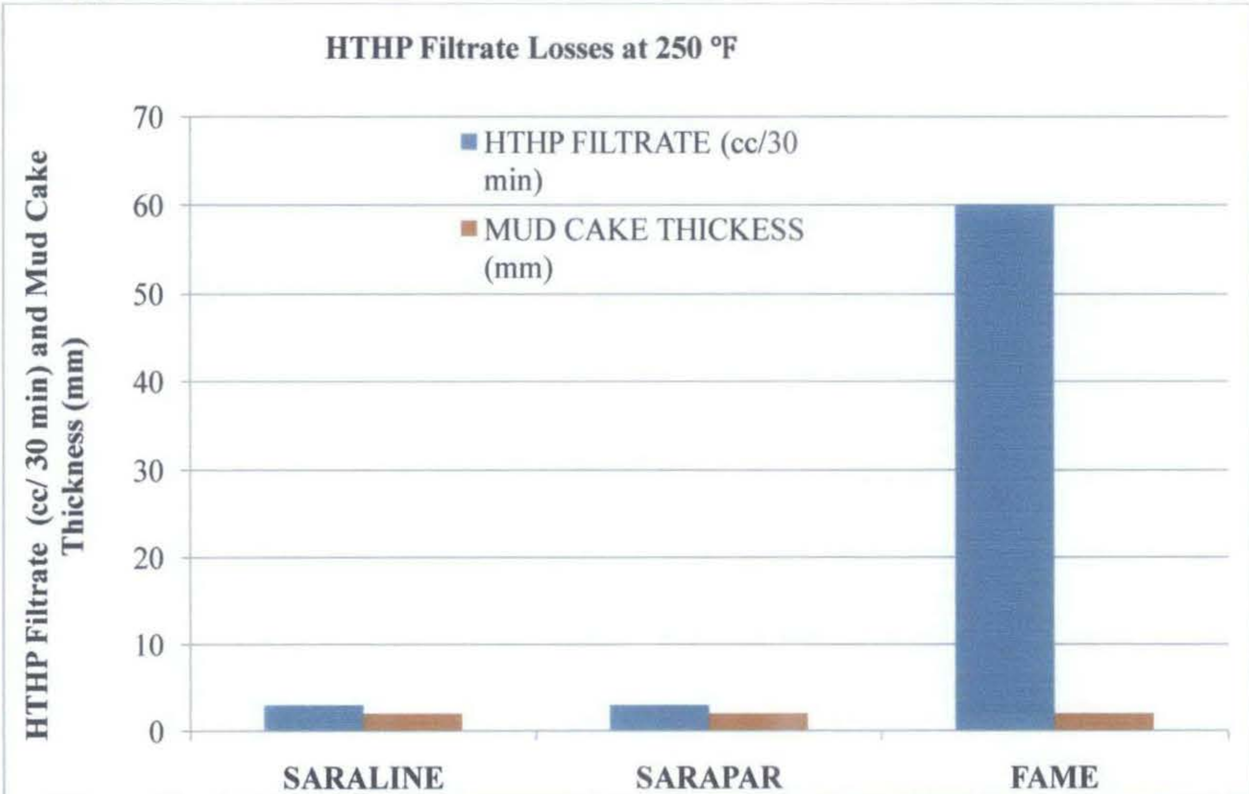


Figure 9: Fluid Loss Properties for First Base Oil Comparative Test

* The fluid loss control for FAME exceeds the maximum 60.

Discussion

The first formulation developed provided a base line upon which the rheological behaviors of the mud can be predicted (refer to appendix Table 5 for specifications selected) All formulations were hot-rolled at 250 °F, for 16 hours. From Figure 6 and Figure 7, before hot rolling, the Plastic Viscosity (PV), Yield Point(YP) and Gel Strength for both mineral oils are lower than Jatropha FAME due to the inherently high viscosity of the Jatropha ester. This showed that future formulations have to be designed to lower the viscosity, either by varying the amounts of viscosifiers or testing the effect of lime and varying it. After hot-rolling, the FAME was too viscous to be accurately measured whilst the mineral based mud remained stable. A possible explanation is that the high viscosity of acid produced during hydrolysis lead to higher viscosity of the mud.

4.2 Second Formulation

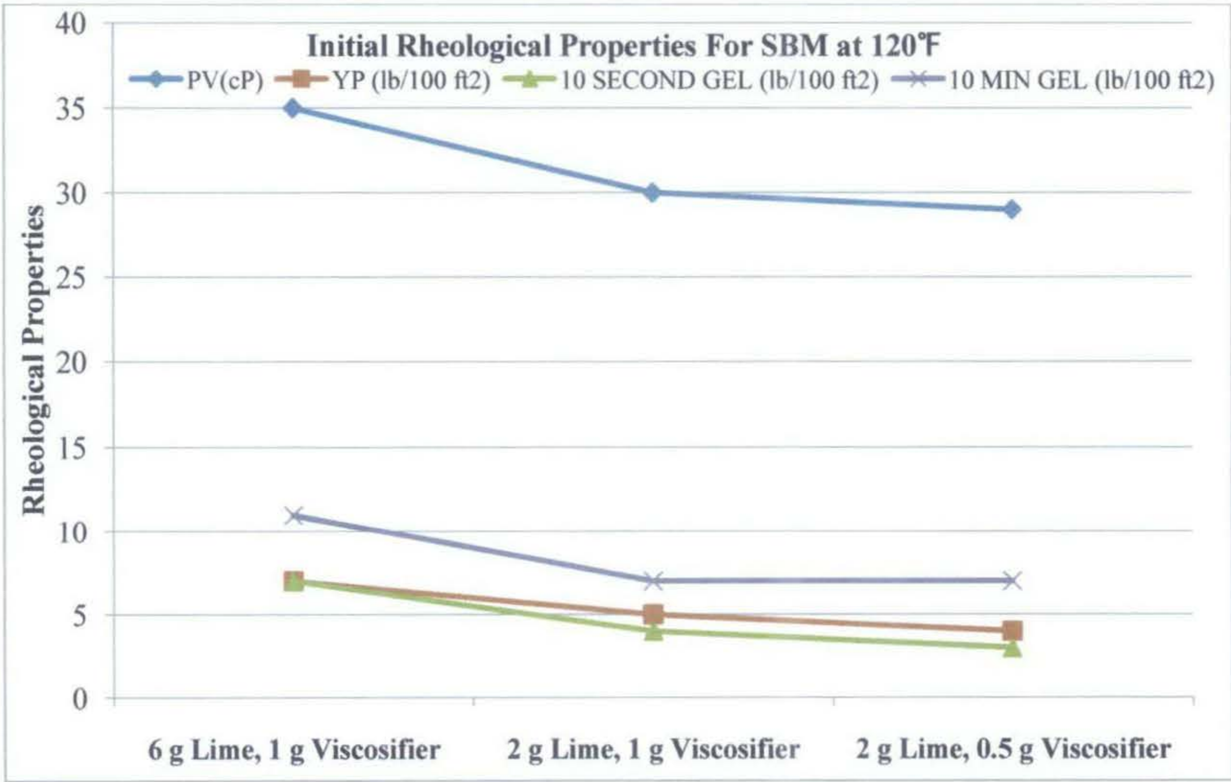


Figure 10: Initial Rheological Properties for Varying Additive Test

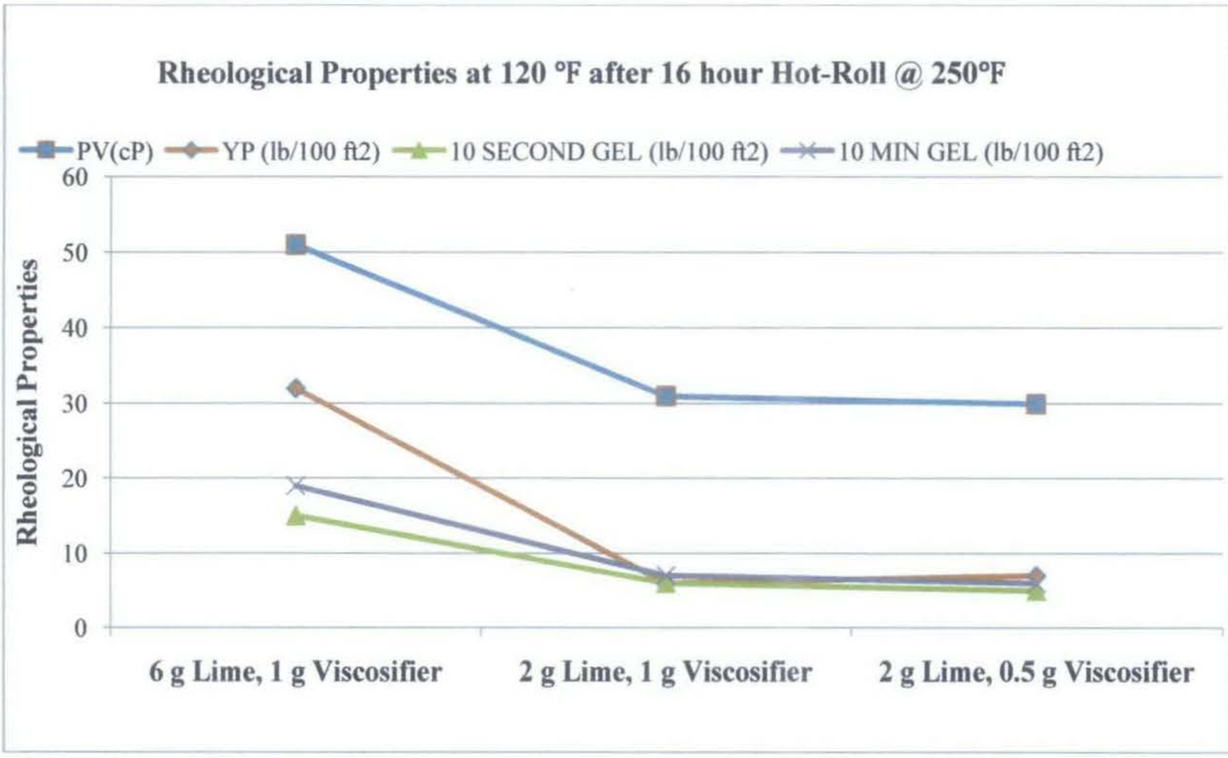


Figure 11: Rheological Properties after 16 Hour Hot-Roll for Varying Additive Test

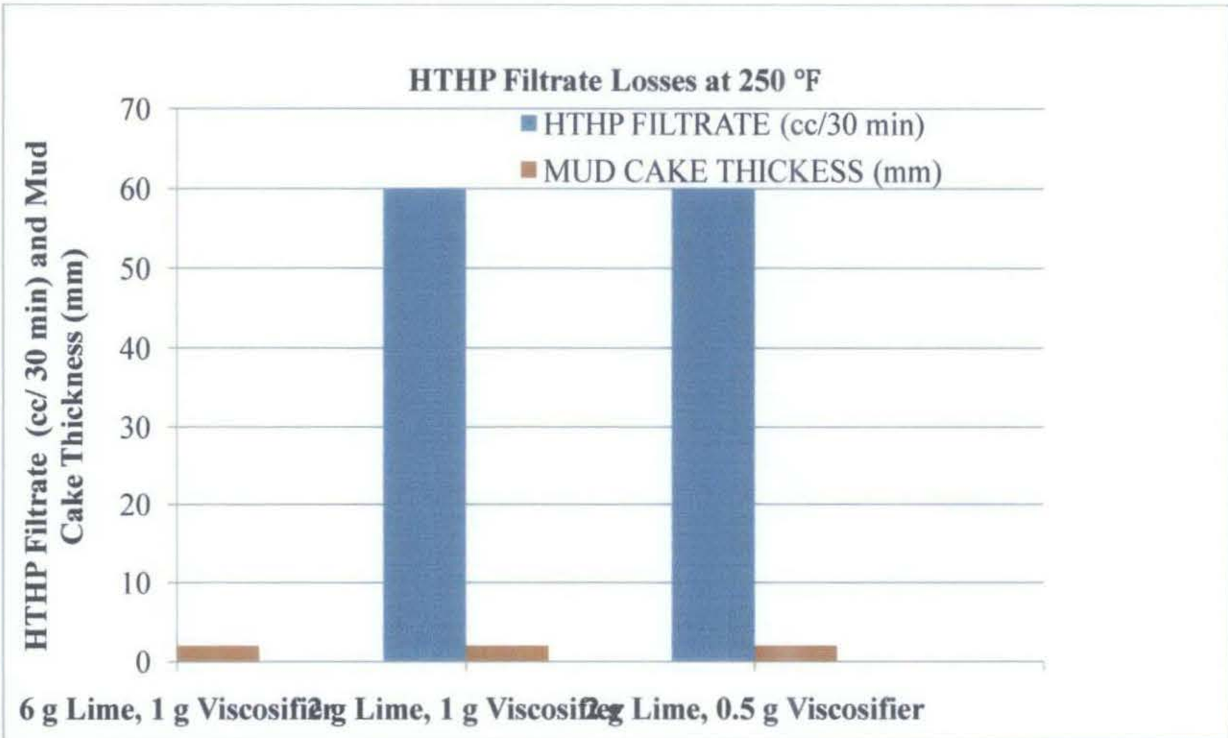


Figure 12: Fluid Loss Properties for Varying Additives Test

* The Fluid Loss exceeds 60 cc for all three formulations

Discussion

For the additive varying test, the results showed that formulations with low lime concentration (2g) showed better rheological properties (lower viscosity and deflocculated) compared to the sample with higher lime concentration. The increase in Yield Point is attributed to the release of Calcium ions from the lime in aqueous solution in high temperature which provides a link between clay particles to increase the initial resistance due to electrochemical forces between particles. The lack of filtration control showed that a better formulation with better fluid loss additives should be used.

4.3 Third Formulation

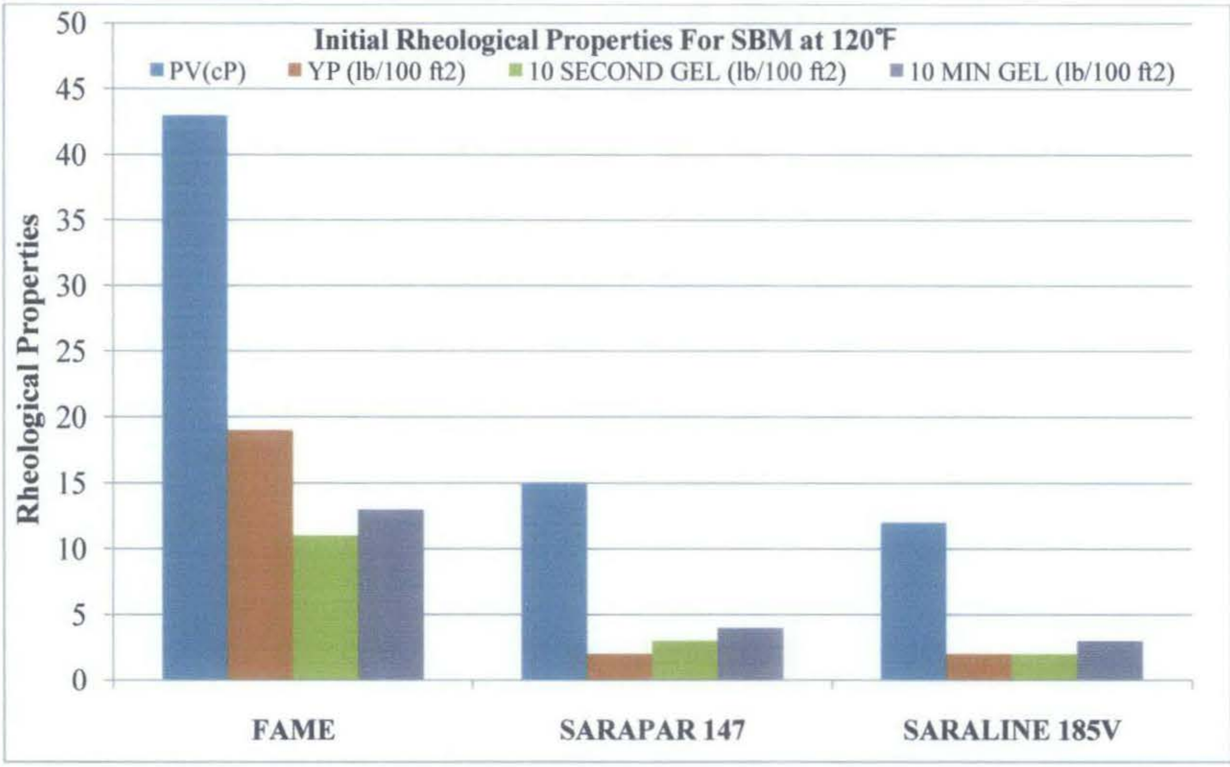


Figure 13: Initial Rheological Properties for Second Base Oil Comparative Test

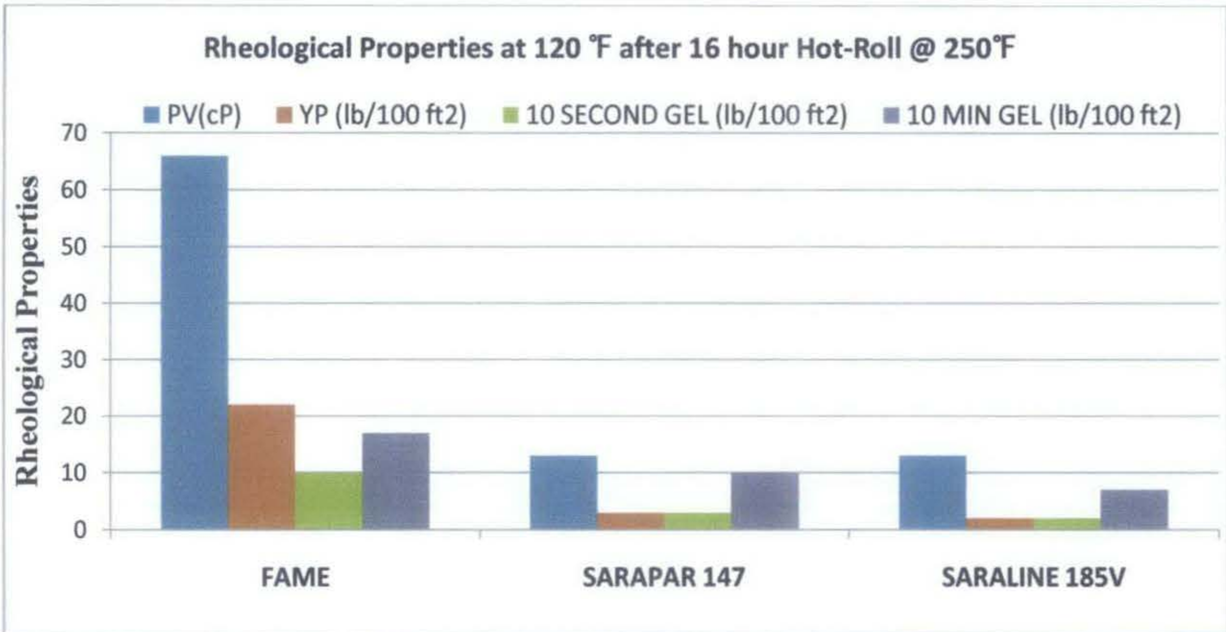


Figure 14: Rheological Properties after 16 Hour Hot-Roll for Second Base Oil Comparative Test

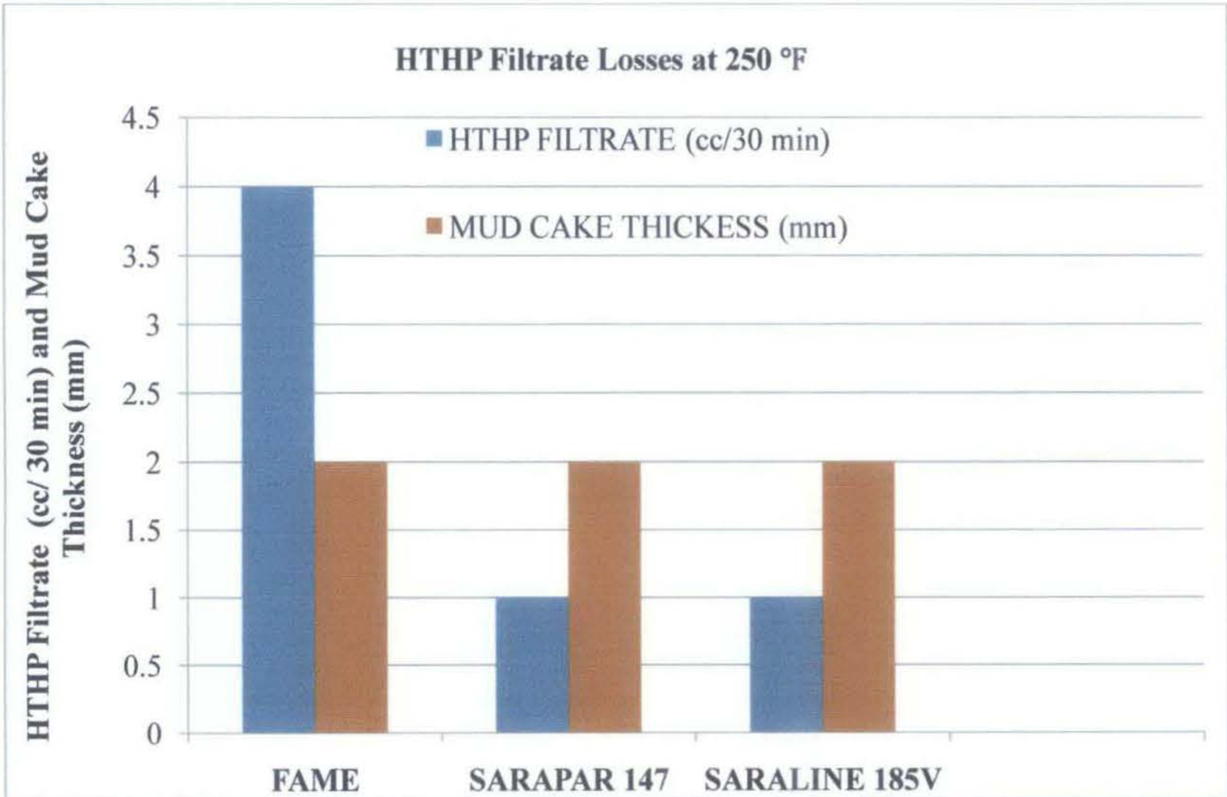


Figure 15: Fluid Loss Properties after 16-Hour Hot-Roll for Second Base Oil Comparative Test

Discussion

The third base oil comparative test was done to gain fluid loss control for the Jatropha FAME. A 1.1 SG mud, with 35% Salinity was formulated. A high temperature emulsion was used, along with high temp fluid loss control. From Figure 12 through 14, it showed that the Rheological properties of Jatropha can be a match for the mineral oil, and fluid loss can be reduced with better additives and emulsions that can withstand high temperatures. The PV and YP for the Jatropha was close to the industry accepted specifications, and with further slight modifications to the formulation better rheological properties can be obtained.

4.4 Formation Damage Test for FAME Based Mud

Permeability Calculation		
TEF	1	
flow rate (ml/min)	5	
viscosity (cp)	2.923	
core length (cm)	7.722	
core diameter (cm)	3.706	
dP (psig)	413.28	
P inlet (psig)	640.84	
P outlet (psig)	524.64	
	dp	pi-po
perm calculate (md) 1	6.20226	22.05912231
perm calculate (md) 2	6.202319228	22.05933297

Figure 16: Initial Permeability Calculation

Permeability Calculation		
TEF	1	
flow rate (ml/min)	5	
viscosity (cp)	2.923	
core length (cm)	7.722	
core diameter (cm)	3.706	
dP (psig)	413.2	
P inlet (psig)	684.64	
P outlet (psig)	251.05	
	dp	pi-po
perm calculate (md) 1	6.203461	5.911737
perm calculate (md) 2	6.20352	5.911793

Figure 17: Permeability after FAME Mud Contact

Discussion

The results recorded from the Formation Damage System showed that at a constant temperature of 60 ℃, and a constant flow rate of 5 ml/min, the permeability change (or formation damage) of the system is nearly negligible at a value of 0.001200825 mD. This is indicative of drilling operations performed at medium temperature wells, and the results are promising. The mud with FAME used as a base oil can be used with little permeability change or formation damage.

CONCLUSION

The aim of the project was to identify the effectiveness of Jathropa Curcas oil as a base fluid, and this was achieved by comparison with conventionally used base oil, which is mineral oil (Sarapar and Saraline).

Three tests were done, each to achieve a separate objective. The first test involved establishing a initial base oil comparison, using formulations with randomly predicted concentrations of additives given the knowledge of its functions. The second involved modifying the additives to achieve the targeted rheological specification which was achieved and can be further improved with slight modifications to suit different specification for different environments. Fluid Loss control was then achieved from the third test, which indicated that the mud using Jaropha oil is comparable in properties to mineral based oil. The final test involved testing the formation damage properties of the mud at 60℃, and this gave encouraging results whereby the change in permeability was negligible.

It was found that the ester derived from Jatropha Curcas oil (FAME) has comparable properties with mineral oil when used as base oil in an Oil Based Mud system.

The Rheological properties including the filtrate losses can be controlled by modifying the additives used to suit the specifications needed (i.e. High Temp products for high temp environments).

Finally, Jatropha FAME is a form of biodiesel, hence it is renewable, and more importantly environmentally friendlier, which means it can be potentially used in environmentally protected areas. This makes its use all the more appealing in the current and future drilling fluid market.

RECOMMENDATION

Future formulations should be designed with the exact specifications required for different environments. The mud should be tested with higher specific gravities to be used in deeper wells. Formulations using higher lime content should also be considered, since most wells produce carbon dioxide and sulfuric gasses, and a low lime content mud would not be suitable to be used. Besides this, the mud should be formulated at higher temperatures, since the global trend of oil and gas exploration is slowly moving towards deepwater conditions at high temperature and high pressure environments. The ultimate test would be to formulate the mud at high temps, and get excellent fluid loss properties.

APPENDIX

Table 4: First Base Oil Comparative Test Formulation

	1		2		3	
Saraline 185V	181.7					
SARAPAR 147			182.3			
JATROPHA FAME					209.2	
CONFI-MUL P	2.0		2.0		2.0	
CONFI-MUL S	4.0		4.0		4.0	
CONFI-GEL HT	6.0		6.0		6.0	
CONFI-TROL HT	8.0		8.0		8.0	
LIME	6.0		6.0		6.0	
Water	58.5		58.6		59.8	
CaCl2	22.52		22.53		23.02	
DRILL-BAR	131.4		130.8		102.1	
Mud weight (ppg)	**10**		**10**		**10**	
OWR	**80/20**		**80/20**		**80/20**	
Rheological properties at 120°F						
600 RPM	41		40		112	
300 RPM	24		23		72	
200 RPM	18		16		56	
100 RPM	12		10		40	
6 RPM	4		3		21	
3 RPM	3		2		20	
PV, cP	17		17		40	
YP, $lb/100ft_2$	7		6		32	
Gel 10 sec, $lb/100ft_2$	5		5		24	
Gel 10 min, $lb/100ft_2$	9		8		29	
Emulsion Stability (Volt)	489		560		1999	
AHR16 hr, F:	**200°F**	**250°F**	**200°F**	**250°F**	**200°F**	**250°F**
600 RPM	51	50	47	47	-	-
300 RPM	31	30	27	28	-	-
200 RPM	21	20	19	19	-	-
100 RPM	14	12	12	12	-	-
6 RPM	6	4	4	4	-	-
3 RPM	5	3	4	4	-	-
PV, cP	20	20	20	19	TTTM*	TTTM*
YP, $lb/100ft_2$	11	10	7	9	TTTM*	TTTM*
Gel 10 sec, $lb/100ft_2$	8	8	9	8	-	-
Gel 10 min, $lb/100ft_2$	17	15	13	20	-	-
Emulsion Stability (Volt)	973	753	994	1033	-	-
HTHP, cc	3	3	3	3	-	-
Water in filtrate	no	no	no	no	-	-

Table 5: Varying Additives Test Formulation

	4		5		6	
JATROPHA FAME	210.8		211.5		211.7	
CONFI-MUL P	2.0		2.0		2.0	
CONFI-MUL S	4.0		4.0		4.0	
CONFI-GEL HT	1.0		1.0		0.5	
CONFI-TROL HT	8.0		8.0		8.0	
LIME	6.0		2.0		2.0	
Water	60.3		60.5		60.5	
CaCl2	23.19		23.30		23.30	
DRILL-BAR	104.9		107.9		108.2	
Mud weight (ppg)	**10**		**10**		**10**	
OWR	**80/20**		**80/20**		**80/20**	
Rheological properties at 120°F						
600 RPM	77		65		62	
300 RPM	42		35		33	
200 RPM	28		24		22	
100 RPM	17		14		13	
6 RPM	6		4		4	
3 RPM	5		4		3	
PV, cP	35		30		29	
YP, $lb/100ft_2$	7		5		4	
Gel 10 sec, $lb/100ft_2$	7		4		3	
Gel 10 min, $lb/100ft_2$	11		7		7	
Emulsion Stability (Volt)	710		1018		915	
AHR16 hr, F:	**200°F**	**250°F**	**200°F**	**250°F**	**200°F**	**250°F**
600 RPM	215	134	67	68	67	67
300 RPM	141	83	37	37	38	37
200 RPM	106	63	26	25	27	26
100 RPM	65	41	16	14	15	15
6 RPM	19	14	4	4	6	4
3 RPM	10	12	4	3	5	3
PV, cP	74	51	30	31	29	30
YP, $lb/100ft_2$	67	32	7	6	9	7
Gel 10 sec, $lb/100ft_2$	29	15	6	6	5	5
Gel 10 min, $lb/100ft_2$	39	19	7	7	7	6
Emulsion Stability (Volt)	**426**	**657**	**496**	**327**	**516**	**358**
HTHP, cc	1	>60	9	>60	8	>60
Water in filtrate	no	yes	no	yes	no	yes

Table 6: Second Base Oil Comparative Test Formulation

Products	Function	SG	FAME		SARAPAR 147		SARALINE 185V	
Jatropha FAME	Base fluid	0.87	191.7					
Sarapar 147		0.77			163.1			
Saraline 185V		0.77					163.1	
Palm Oil								
EM348 Mod 1	HT Emulsifier	0.95	10.0		10.0		10.0	
XP TROL F	Liquid fluid loss additive	0.98	2.5		2.5		2.5	
CONFI-GEL HT	Organophilic clay viscosifier	1.60	1.0		1.0		2.0	
CONFI-TROL 450	Fluid loss additive (gilsonite)	1.30	4.0		4.0		4.0	
CONFI-TROL HT	Polymeric fluid loss additive	1.03	4.0		4.0		4.0	
LIME	Alkalinity	2.30	5.0		5.0		5.0	
Drillwater	Brine	1.229	55.1		53.7		53.7	
Calcium Chloride			32.1		31.4		31.3	
DRILL-BAR	Weighing agent	4.28	156.7		187.2		186.6	
Aging Temperature / F		200	FAME		SARAPAR 147		SARALINE 185V	
Aging Period / Hour		16		16		16		16
Aging Type D = Dynamic, S = Static		D or S		D		D		D
Testing temperature / F		120 or 150	120	120	120	120	120	120
Mud weight	SG							
Rheological properties								
600 RPM			105	154	32	29	26	28
300 RPM			62	88	17	16	14	15
200 RPM			46	63	15	11	10	11
100 RPM		>30	30	38	9	7	6	6
6 RPM		6 - 10	11	10	3	2	2	2
3 RPM		5 - 9	10	9	2	1	1	1
PV	cP	25- 45	43	66	15	13	12	13
YP	lb/100 ft^2	10 - 20	19	22	2	3	2	2
Gel 10 sec	lb/100 ft^2	10 - 20	11	10	3	3	2	2
Gel 10 min	lb/100 ft^2	20- 40	13	17	4	10	3	7
Gel 30 min	lb/100 ft^2							
ES	volts	>600	1999	1785	1468	897	1333	980
Excess lime	lb/bbl		Not		Not		Not	
HTHP filter loss (500 psi, 350 F)	Total, cc/30 min	<4	Not	4.0	Not	1.0	Not	1.0
Cake thickness (mm)	mm		Not	2	Not	2	Not	2

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