STUDY OF CASTOR OIL AS OIL BASED FLUID IN DRILLING OPERATION

By

MUHAMMAD SYAMIM BIN HUSSAIN

12764

A Project dissertation submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Petroleum Engineering)

JAN 2013

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

…………………….
(Ms. Raja Rajeswary)
Project Supervisor

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.

Regards,

……………………………
(Muhammad Syamim Hussain, 12764)

ABSTRACT

Drilling fluids are fluids that are made from the mixture of natural and synthetic chemical compounds (Fadairo et al., 2012). It is an important component in drilling operation because it is used to cool and lubricate the drill bit, clean the well, carry cuttings to the surface, control formation pressures and improve the function of drill strings and tools in the hole. Drilling fluids can be divided into two types: water based mud (WBM) and oil based mud (OBM). The usage of these two types of mud are dependent on the drilling and formation needs as well as the requirements for disposition of the drilling fluids after it is no longer needed. Usually nowadays, most drilling operation is using diesel as base oil for OBM.

The usage of diesel oil based mud will lead to environmental problem especially marine environment in offshore drilling operation. This is because of the toxicity of certain aromatic compounds found in diesel based mud. In offshore applications, tighter environmental regulations are forcing the transport of diesel based oil to shore or the development of special cuttings-handling equipment. Low toxicity oil-based mud should be produced in order to avoid the environmental problems.

Many researches had been conducted to find good oil in order to replace diesel oil. Various bio-diesel oils had been introduced to substitute diesel based oil in drilling fluids. Some basic considerations are needed to be concern in choosing a drilling fluid. For example, a good drilling fluid should have the pour point and viscosity as low as possible and a high flash point above the maximum temperature of the well.

This project is mainly about oil based mud (OBM). Basically, the proposal discusses the basic understanding of the chosen topic, which is the study of castor oil as Base oil in OBM. In order to find substitute for diesel oil, castor oil is being used as the base oil. This project will involve some lab works to test the rheological properties and elastomeric effects in order to identify the sustainability of as an alternative of biodiesel oil to replace diesel oil in drilling fluids.

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Table of Contents

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND NOMENCLATURES

HPHT	High pressure high temperature
T-1	Testing of mud samples no 1 for HPHT system
ppg	Pound per gallon
ASTM	American Standard Testing Method
PPM	Parts per million
RPM	Revolutions per minute
API	American Petroleum Institute
OWR	Oil Water Ratio
wt %	Weight percent
SG	Specific Gravity
ES	Electrical Stability
OBM	Oil based mud
WBM	Water based mud

CHAPTER 1

INTRODUCTION

1.1 Background of study

During drilling operation, the drilling fluids known as drilling mud is circulated from the reserves tank called mud tank trough the arrangement of pipes and drilling tubes into the wellbore. Drilling fluids are being circulated into the wellbore by using a special pump installed on the surface called as mud pump.

Drilling fluids are fluids that are made from the mixture of natural and synthetic chemical compounds. It is an important component in drilling operation because it is used to cool and lubricate the drill bit, clean the well, carry cuttings to the surface, control formation pressures and improve the function of drill strings and tools in the hole. Drilling fluids can be divided into two types: water based mud (WBM) and oil based mud (OBM). Oil based mud (OBM) have is most widely used (oil field chemical book, chapter 1).

In general, OBM are drilling fluids which have oil as their dominant or continuous phase. A typical OBM composition are clay and sand about 3%, salt about 4%, barite 9%, water 30% and oil 50-80%. OBM are base on non aqueous drilling fluid (NAF) that is distilled from crude oil; they include diesel, mineral oils and refined linear paraffin (LPs) (Drilling Fluid processing handbook, 2005). OBM is widely used because of their distinct advantages over water based mud. For example, thermal stability in deep and high temperature wells, increased lubricity in deviated offshore wells, hole stability in thick and water sensitive shale, corrosion inhibition, tolerance of contamination , borehole stability and ease of maintenance. OBM have a whole lot of advantages because of its various desirable rheological properties that oils exhibit. In history, since 1930s, it has been recognized better productivity is achieved by using oil rather than water as the drilling fluid. The basic kind of oil used in formulating OBM is the diesel oil, which has been in existence for a long time, but over the years, diesel oil based mud have posed various environmental problems. This is due to high toxicity and aromatic contents exposure to the people and environment.

In response to the harmful effects of diesel oil on the environment, researches and surveys have gone on in the past two to three decades, and have come up with mud formulations based on the use of plant oils or also called vegetable oil as diesel substitutes. Nowadays, plant oil is rapidly becoming popular in the raw materials market for diesel substitutes. Normally, plant oil that being used as based oil in drilling fluids are first converted into biodiesel oil. This biodiesel oil is then being used as based oil in oil based mud. Linear Alkyl Benzene (LAB) is blended together with the plant oil to change the oil into straight vegetable oil (SWO). Castor oil is the alternative oil used in this project to substitute diesel oil in drilling fluids. Castor oil is harmless to environment since it has low aromatic content and less toxic. Even though it is harmless but castor oil properties need to be measured. This is done to measure sustainability of castor oil to replace diesel in drilling fluids. These properties are being measured by doing experiments and testing in laboratory.

1.2 Problem statements

OBM has been used in drilling operation for ages. Commercially used OBM is diesel oil based mud. Diesel oil gives good advantages to drilling operation but at the same time it gives certain bad advantages. Diesel oil is very harmful to environment since it has high aromatic content and high toxicity (Setyawan, W.,et al, 2011)

By having an alternative oil to be used in drilling fluid, it might help in reducing the environmental problems caused by diesel oil. Thus, plant oil is a good alternative to diesel oil and castor oil might be the suitable plant oil to replace diesel oil. Castor oil can be a potential biodiesel oil to be use because it is produced locally, it can be grown either as pure crop in rotation with wheat, linseed etc. and the comparative advantages of castor is that its growing period is short. However castor oil is distinguished by its high content (over 85%) of ricinoleic acid. It also has high fatty hydroxyacids, high molecular weight (298), low melting point (5°c) and most of all for highest and stable viscosity of any plant oil.

Castor oil will be tested in order to prove the reliability, if it is environmental friendly and economical alternative to replace diesel oil in drilling fluids. The rheological properties of castor will be measured and tested with various tests.

1.3 Objectives

The objectives of this study are:

1. To measure the rheological properties of castor oil.
2. To identify if castor oil is a good oil to be use as continuous phase in oil based mud.

1.4 Scope of study

The research will involve in the understanding of oil based mud. The study of this project can be broken down to the identification of the appropriate biodiesel oil to be use as continuous phase in oil based mud and the method of studying and evaluating properties of the formulated mud.

The scope of study is mainly about studying the rheological properties of castor oil. The study will be divided into two stages;

1. Involve the basic properties of the Castor oil and determining an ideal formulation to be developed.

2. To focus on experimental work in the lab to see the effectiveness of castor oil as base fluid in OBM.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 Castor Oil

Castor oil is colorless or pale yellowish oil extracted from the seeds of the castor oil plant, Castor (Ricinus communis L) is cultivated around the world because of the commercial importance of its oil. The Indian variety of castor seed has an oil content of 48% and 42% can be extracted. Castor grows well under hot and humid tropical conditions and has a growing period of 4 to 5 months. Castor oils unsaturated bond, high molecular weight (298), low melting point (5°C) and very low solidification point (−12°C to −18°C) make it industrially useful, most of all for the highest and most stable viscosity of any vegetable oil (Shrirame et al, 2011). Castor oil is a new alternative for plant-oil based mud that is potential to be developed locally, environmentally friendly, and able to meet the standard requirement of OBM. Castor oil has specific gravity (SG) of 0.958-0.968 (diesel oil has SG of 0.84 in 60° F (API, 1998) and viscosity of 9.5-11 centipoise in 68°F (Jamieson, 1943). However, regardless of its country of origin or season in which it was grown, its chemical composition remains relatively constant as shown in Table 1. Like other vegetable oil, castor oil is a triacylglycerol composed of various fatty acids and glycerol. Castor oil is distinguished by its high content (over 85%) of ricinoleic acid. No other vegetable oil contains so high a proportion of fatty hydroxyacids and varying small amounts of saturated and unsaturated fatty acids. The high content of ricinoleic acid is the reason for the high value of castor oil and its versatile application possibilities in the chemical industry. The physical properties of the vegetable oil are shown in Table 2. Castor oil has multipurpose usage, such as in the manufacturing of a number of industrial chemicals like surfactants, specialty soaps, surface coatings, cosmetics and personal care products, pharmaceuticals, etc (Shrirame et al, 2011). In some tropical countries, castor oil has been used as a lubricant for heavy machines such as locomotives (Jamieson, 1943).

Table 1 Castor oil chemical properties

Fatty Acid	Percentage
Ricinoleic Acid	89.5 %
Linoleic Acid	4.2 %
Oleic Acid	3 %
Stearic Acid	1 %
Palmitic Acid – 1%	1 %
Dihydroxystearic Acid	0.7 %
Linolenic Acid	0.3 %
Eicosanoic Acid	0.3 %

Table 2 Vegetable oil physical properties

Oil	Kinematic viscosity at 20oC	Kinematic viscosity at 40oC	Kinematic viscosity at 70oC	Density	Acid value	Glycerol
Castor	961	268	61.9	993	0.022	4.12
Cotton seed	85.0	43.7	23.2	951	7.073	18.40
Groundnut	91.8	41.4	27.6	942	3.185	5.43
Moringa Oil	53.7	39.1	21.7	919	22.754	11.47
Rubber seed	44.0	39.9	33.0	920	10.814	4.00
Soya Bean	74.1	35.8	30.7	950	0.669	5.50
Sunflower	78.9	45.6	24.7	953	2.124	7.64
Petroda diesel	22.8	12.3	8.53	879	4..17 x10-4	0.70

2.2 Typical Extraction of oil from Oilseeds Oilseed extraction

Kg of oil from 100 kg of oilseed (Shrirame et al, 2011)

Table 3 Oil Seed Extraction

Castor	**36**
Palm	**36**
Rapeseed	**37**
Soybean	**14**
Sunflower	**32**

2.3 Yield Comparison of Castor oil with other Plant Oil Biodiesel

Crop oil in Liters per hectare. (Shrirame et al, 2011)

Table 4 Crop oil production

Castor	**1413**
Palm	**952**
Rapeseed	**779**
Soybean	**5950**
Sunflower	**446**
Coconut	**2689**

2.4 Biodiesel

Biodiesel oil can be defined as medium length (C16 to C18) chains of fatty acids, and is comprised mainly of mono-alkyl fatty acid esters (Forero, *Biodiesel from castor oil: a promising fuel for cold weather*). It is said that biodiesel having an advantage of being non-toxic, biodegradable and essentially free of sulphur and carcinogenic ring components. Many researches had been done in order to use vegetable oil as an alternative to diesel oil. Even though, biodiesel has numerous advantages it too has some drawbacks. At low temperatures, biodiesel turns into wax crystals.

2.4.1 Cold Flow properties

During low temperature operations, cloud point and pour point are very important parameters that need to be take care off. Pour point is the temperature at which the amount of wax out of solution is sufficient to gel the oil. It is also indicate the lowest temperature at which the oil can flow. While cloud point is means the temperature at which wax first become visible when the fuel is cooled.

2.4.2 Bio-Diesel Produced from castor oil

The major problem associated with the use of pure vegetables oils as biodiesel is caused by high viscosity (Shrirame et al, 2011). Due to Castor oil high viscosity and low volatility, dilution, micro-emulsification, pyrolysis and transesterification are the four techniques applied to solve the problem encountered. Transesterification is a promising solution to these problems. This process involves chemical conversion of the oil to its corresponding fatty ester and thus biodiesel.

2.4.3 Biodiesel Based Drilling Fluids

Biodiesel is synthesized by interesterification. Oil crops, wild-bearing crops, engineering micro algae, vegetable oil, fats and hogwash oil can be used as the raw materials of interesterification. Biodiesel is renewable and can replace mineral diesel. The main component is fatty acid methyl ester (FAME). The biodiesel has maximum moisture content of 30%-45%, relative density of 0.8724-0.8886 (Dong Fang, 2012), good lubrication performance, environmental friendly, low sulphur content, low sulfur oxide and sulfides, emission, biodegradation is high up to 98% which is twice the mineral diesel, it can reduce accidental leakage pollution (SunPing, 2002), good safety performance, high flash point, good in health, safety and environment issue. In the preparation of ethyl ester (biodiesel), five distinct stages will be involved (Shrirame et al, 2011);

1) Heating of oil.
2) Preparation of alkaline mixture.
3) Adding of alkaline alcohol to oil and stirring the mixture.
4) Settling of separation of glycerol.
5) Washing of ethyl ester with water.

2.4.4 Rheological Behavior of Biodiesel Based Drilling Fluid

Rheological behavior of biodiesel was considered at room temperature and compared to white oil. Apparent viscosity (AV), plastic viscosity (PV), and yield point (YP) of white oil, biodiesel oil, aged oil and aged biodiesel are being observed. The viscosity of biodiesel is lower than white oil, which is advantageous to the preparation of high density drilling fluid. The deviation of the viscosity of biodiesel before and after aging is smaller than white oil, which indicates good stability of biodiesel at high temperature, so biodiesel can be used as base oil of drilling fluids for drilling operation at high temperature reservoir and formation.

Biodiesel not only exceeds the performances of normal oil-based drilling liquids but shows excellent environmentally compatibility as well. It is said to be environmentally friendly because it contain low sulfur content, without aromatic alkenes, easily biodegradable. Besides, biodiesel has good safety performance like high flash point and not hazardous. On the other hand, biodiesel is renewable which is in line with the strategy of sustainable development (ChenXiu, 2010).

2.5 Base Fluid Properties

There are certain requirements to identify whether the oil can be use as base fluid in drilling fluid. The requirements are as follows;

2.5.1 Kinematic Viscosity

It should be as low as possible. This allows the oil based mud to be formulated at lower oil/water ratio and gives better rheology (lower plastic viscosity) especially at lower mud temperature.

2.5.2 Flash Point

It should be greater than 100°F. Higher flash point will minimize fire hazards as less hydrocarbon vapors is expected to generate above the mud flash point.

2.5.3 Pour Point

It should be lower than the ambient temperature to allow pump ability of mud from storage tanks (http://en.wikipedia.org/wiki/Pour_point, 2013)

2.5.4 Non-toxic and low aromatic content

Base oil should have total aromatic hydrocarbon content of less than 5%. It should be non-acutely toxic in a standard 96 hr LC 50 toxicity test, performed using 100% water soluble fraction of the base

2.6 Rheological Study

Rheology is the study of the deformation and flow matter (ASME Shale Shaker Committee, 2005). Rheology of fluids in the well is the relationship between the flow rate and the pressure required to maintain the flow rate (either in pipe or annulus). The relationships between these properties will affect circulating pressures, surge and swab pressures and hole cleaning ability. In this project, the rheological study comprises of plastic viscosity, yield point, electric stability and gel strength. Each study is so significant to choose a better base fluid.

2.6.1 Plastic Viscosity

Viscosity is a measure of the resistance of a fluid which is being deformed by either shear stress or tensile stress. In everyday terms (and for fluids only), viscosity is "thickness" or "internal friction". Thus, water is "thin", having a lower viscosity, while honey is "thick", having a higher viscosity. Simply, the less viscous the fluid the greater its ease of movement (Keith, S. 1971). Plastic viscosity relates to the resistance to flow due to interparticle friction. The friction is affected by the amount of solids in the mud, the size and shape of those solids and the viscosity of the continuous liquid phase.

Readings are taken from viscometer. Using the formula below to get Plastic Viscosity;

Plastic Viscosity, PV= [600rpm Reading] – [300 rpm Reading]

Unit: **centipoises, cp**

Normally, the higher the mud weight, the higher the PV will be. (Jetjongjit, R. 2010). However, if you have an increasing trend of PV without mud weight change, it means that there is an increase in ultra-fine drill solid content in the mud system. Moreover, if you use oil base mud, please keep in mind that emulsified water in oil base drilling fluid will act like a solid, and it will increase the PV dramatically.

2.6.2 Yield Point

Yield point estimates the portion of the total viscosity that comes from attractive forces between particles suspended in the mud. (Chilingarian et.al)

Yield Point, YP = [300rpm Reading] – PV

In oil-based mud, increase of YP can be cause by;

1. Drill solid – YP will be higher if high drill solid present
2. YP will be high in low temperature environment.

2.6.3 Electric Stability

The electric stability (ES) of an oil-based drilling fluid mud is a property related to its emulsion stability and oil-wetting capability. ES is determined by applying a voltage ramped sinusoidal electrical signal across a pair of parallel flat-plate electrodes immersed in the mud. The resulting current remains low until a threshold voltage is reached, whereupon the current rises very rapidly. Maximum voltage that the mud will sustain across the gap before conducting current is displayed as the ES voltage (SPE Drilling & Completion *9*, no. 1, 1994). Specification value: > 600volts

2.6.4 Gel Strength

The gel strength is the shear stress of drilling mud that is measured at low shear rate after the drilling mud is static for a certain period of time (Jetjongjit, R. 2010) but they routinely measured after 10 seconds (initial gel strength) and 10 minutes. Gel strength are determined in two-speed direct-indicating viscometer by slowly turning the driving wheel on top of the instrument by hand and observing the maximum deflection before the gel breaks. Gel strength also can be measured with a rheometer or shearometer (canon, F. 1999).

Specification value;

Gel 10sec: **10 – 20 lb/100ft2**

Gel 10min: **20 – 40 lb/100ft2**

2.6.5 Viscosity

Viscosity of fluids defined as the resistance of fluids to flow. Viscosity measured in the unit of poise which is equivalent to dyne-sec/cm2. One poise represents a high viscosity; therefore the general unit that represents the fluid is centipoise. A centipoise is equivalent to 1/100 poise or 1 millipascal-second. This property of fluids is significant in hole cleaning to control the settling rate of drill cuttings generated by the drill bit through moving fluid and bring them up to the surface.

There are two main apparatus that the author has utilized in the laboratory which are marsh funnel and direct indicating viscometer. Marsh funnel is a simple device for routine measurement of drilling fluids viscosity. The viscosity measured through this apparatus is known as funnel viscosity. The Marsh funnel is dimensioned so that the outflow time of one quart freshwater (946 cm^3) at a temperature of 70° ± 5°F (21° ± 3°C) is 26 ± 0.5 seconds. Thus, fluid which records a time more than 26 ± 0.5 seconds using the marsh funnel is more viscous compared to freshwater and vice versa.

2.6.6 Filtration

Filtration control is one of the main factors considered essential in drilling. Filtration measures the relative amount of fluid loss through permeable formations or membranes when subjected to pressure. Thus, it is important to minimize the filtrate invasion to the formations. When drilling permeable formations, filtration rate is often the most important property where the hydrostatic pressure exceeds the formation pressure. Proper control of filtration improves the borehole stability chemically. This is because controlling the fluid loss minimizes the potentially detrimental interaction between the filtrate and the formation. Filtrate invasion may be controlled by the type and quantity of colloidal material and by filtration control materials.

2.6.7 Elastomers

Oil based drilling fluids can chemically alter the properties of elastomers used in drilling equipment, severely affecting life and function. The products affected include O-ring, blowout preventers (BOPs), pulsation dampeners, downhole mud motors and drilling bits. This study centers on the effects of selected environmentally safe Castor oil based mud on elastomers and logging tools.

The performance of elastomers in Castor oil drilling fluid is strongly dependent upon fluid chemistry, operating temperature and the type of elastomer chosen for service. Caution and testing have to be done when selecting environmentally safe drilling fluids and compatible elastomers.

2.6.8 Density Measurement

Based oil samples expand as increase in temperature under condition of isobaric, while decrease in thermal expansion with increase of pressure under isothermal condition (Azrai, R. 2010). Blended vegetable oil with mineral oil is proved to me more tolerance at High Pressure High Temperature scenario and it could be good and suitable candidate for drilling mud. On the other hand, mineral based oil is more compressible compared to blended vegetable oil. In addition, blended vegetable oil is more renewable and sustainable resource.

2.7 Environmentally Safety Indication of Drilling Fluid

An acute toxicity test (96-h, LC50) is of the measuring test to evaluate the toxicity of diesel based fluids using Mysidopsis bahia (Sunde, E. 1991). The results have shown that LC50 values close to 2,000 ppm are toxic according to US Environmental Protection Agency mud and cutting discharge regulation (EPA) (Reis, J. 1996). In contrast, drilling fluids formulated with mineral oil showed LC50 of 1,000,000 ppm, which is considered as non-toxic under the EPA criteria. The difference is due to the high toxicity of the aromatic hydrocarbons present in diesel (G. Sáchez et al, 1999).

2.7.1 Toxicity Test

Median lethal concentration (LC50) value is the concentration of toxicant that kills 50% of the tested organism in a given exposure time. The suspended particulate phase, SPP, was obtained from the drilling fluids and used for toxicity test on marine shrimp and estuarine fish, both are marine organisms. High LC50 values correspond to low toxicity levels and vice versa. Drilling cuttings were also tested following the same procedure of LC50 in order to compare their toxicity levels before and after the application of the bioremediation method.

2.7.2 Biodegradation Tests

According to OEDC protocols aerobic biodegradability test was done by testing the biochemical oxygen demand (BOD) for poorly soluble substances (OEDC Guidelines, 1992). The closed bottle test measures the BOD and express biodegradation as a percentage of the chemical oxygen demand of the substance (COD). Glucose used as reference compound. Dissolved oxygen was measured in triplicate bottles once per week. It is considered that an organic compound is readily biodegradable when the biodegradation reaches 60% within 10 days after achieving an initial 10% of biodegradation, but it must end before day 28 of the testing period (OEDC Guideline, volume 2)

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

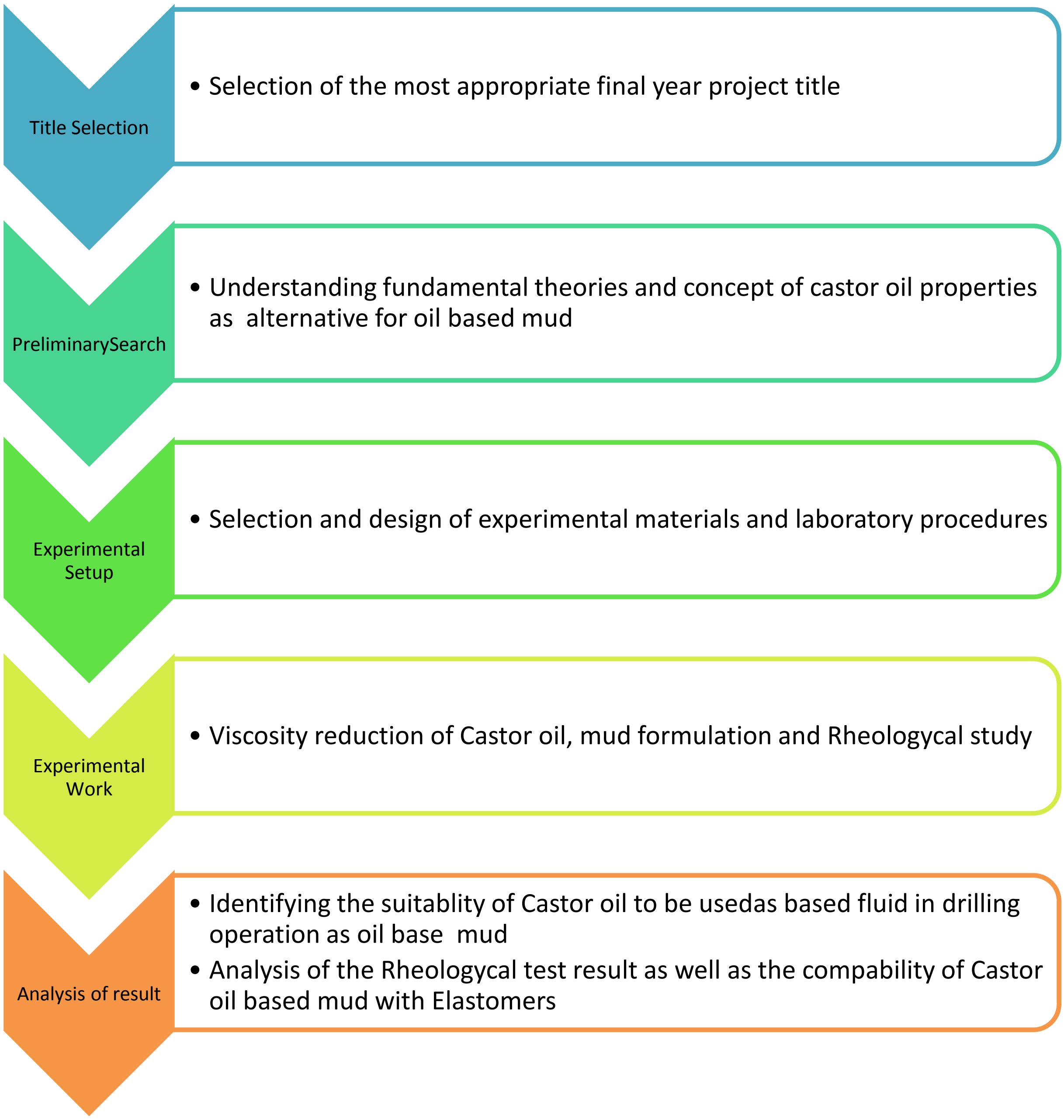

Figure 1 General Methodology Flow chart

3.2 Addition of Methyl-benzene (Toluene) to Castor oil as simple viscosity reduction process

The most common methods used to reduce oil viscosity in the Biodiesel industry are called transesterification. The problem with the transestrification refining method is that it is relatively expensive and produces a quantity of glycerin byproduct that has to be processed again before it has any value. The final fuel product has detergent qualities that can clean out existing fuel tanks and the resulting debris is prone to clog fuel filters for a while. So, to reduce oil viscosity in a less expensive and much lesser time consuming way, addition of solvent preferably Alkyl-benzene are need to be done. This is because addition of Alkyl-benzene reduces the density of the oil and thus decreases the oil viscosity. The purpose of making a solvent blended bio fuel is to thin the resulting blended oil to near the viscosity of diesel oil and reduce its gel-point. The resulting solution should be a uniform solution without precipitates. Vegetable oils are an attractive renewable source for alternative diesel fuels. However, the relatively high kinematic viscosity of vegetable oils must be reduced to make them more compatible with conventional compression-ignition engines and fuel systems. Co solvent blending is a low-cost and easy-to-adapt technology that reduces viscosity (and gel point) by diluting the vegetable oil with a low-(molecular weight solvent), which is in our case is Methyl-benzene (Toluene).

Blending methods vary; however, the most common method of making Blended Bio fuels Diesel (BBD) is to blend the solvent with the source vegetable oil because blending solvents with vegetable oils has three basic functions. Blending reduces the viscosity of the source oil, reduces its gel-point, and tends to force water, and other contaminants, out of solution. This means that thinned oil will drop its contaminant load much more quickly than the more viscous source oil.

3.3 Mud Formulation of Base Fluid

Before rheology test being conducted, mud formulation should be done for each base fluid that going to be tested. Table below shows the mud formulation for Castor oil and Saraline/diesel oil.

Table 5 Mud composition

Composition	Test 1	Test 2	Test 3	Test 4	Test 5
Saraline 185v	183.6	-	-	-	-
Castor oil		230.14	138.084	92.056	46.028
Toluene	-	-	92.056	138.084	184.112
VERSAPRO lb/bbl	8	8	8	8	8
VERSAGEL lb/bbl	7	7	7	7	7
VERSATROL, lb/bbl	8	8	8	8	8
Water, bbl	59	67.31	67.31	67.31	67.31
$CaCL_2$	20.9	12.64	12.64	12.64	12.64
Mil-Bar, lb/bbl	129.46	1.88	1.88	1.88	1.88
Lime, lb/bbl	4	4	4	4	4

3.4 Determination of drilling fluid density (rheology)

Principle

A procedure is given for determining the density. The density of drilling fluid is expressed as grams per cubic centimeter, kilograms per cubic meter, pounds per gallon or pounds per cubic foot. Equipment used to measure the mud density is called MUD BALANCE

Procedure

1 The instrument base should be set on a flat, level surface.

2 Measure the temperature of the drilling fluid and record.

3 Fill the clean, dry cup with drilling fluid to be tested; put the cap on the filled drilling-fluid holding cup and rotate the cap until it is firmly seated. Ensure that some of the drilling fluid is expelled through the hole in the cap, in order to free any trapped air or gas.

4 Holding the cap firmly on the drilling-fluid holding cup (with cap hole covered), wash or wipe the outside of the cup clean and dry.

5 Place the beam on the base support and balance it by moving the rider along the graduated scale. Balance is achieved when the bubble is under the centerline.

6 Read the drilling fluid density at the edge of the rider toward the drilling-fluid cup. Make appropriate corrections when a range extender is used.

Below is the picture of mud balance

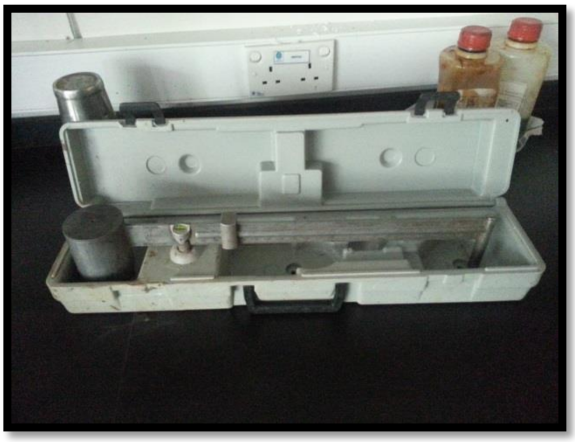

Figure 2 Mud Balance

3.5 Viscosity and gel strength (rheology)

<u>Principle</u>

Viscosity and gel strength are measurements that relate to the flow properties (rheology) of drilling fluids. Equipment use for this test is Viscometer. The following instruments are used to measure viscosity and/or gel strength of drilling fluids:

a) Marsh funnels — a simple device for indicating viscosity on a routine basis;

b) direct-indicating viscometer — a mechanical device for measurement of viscosity at varying shears rates.

3.5.1 Determination of viscosity using the Marsh funnel

Procedure

1. Cover the funnel orifice with a finger and pour freshly sampled drilling fluid through the screen into the clean, upright funnel. Fill until fluid reaches the bottom of the screen.

2. Remove finger and start the stopwatch. Measure the time taken for mud to fill in the cup.

3. Measure the temperature of the fluid, in degrees Celsius (degrees Fahrenheit).

3.5.2 Determination of viscosity and/or gel strength using a direct-indicating viscometer

Procedure

1. Place a sample of the drilling fluid in a thermostatically controlled viscometer cup. Leave enough empty volume (approximately 100 cm3) in the cup for displacement of fluid due to the viscometer bob and sleeve. Immerse the rotor sleeve exactly to the scribed line. Measurements in the field should be made with minimum delay from the time of drilling fluid sampling. Testing should be carried out at the maximum recommended operating temperature is 90 °C (200 °F). If fluids have to be tested above this temperature, either a solid metal bob, or a hollow metal bob with a completely dry interior should be used.

2. Heat (or cool) the sample to the selected temperature. Use intermittent or constant shear at 600r/min to stir the sample while heating (or cooling) to obtain a uniform sample temperature. After the cup temperature reaches the selected temperature, immerse the thermometer into the sample and continue stirring until the sample reaches the selected temperature. Record the temperature of the sample.

3. With the sleeve rotating at 600rpm, wait for the viscometer dial reading to reach a steady value (the time required is dependent on the drilling fluid characteristics). Record the dial reading *R*600 in Pascal for 600rpm

4. Reduce the rotor speed to 300 rpm and wait for the dial reading to reach steady value. Record the dial reading *R*300 in Pascal for 300 rpm.

5. Stir the drilling fluid sample for 10 s at 600 rpm.

6. Allow drilling fluid sample to stand undisturbed for 10 s. slowly and steadily turn the hand-wheel in the appropriate direction to produce a positive dial reading. Record the maximum reading as the initial gel strength. For instruments having a 3 rpm speed, the maximum reading attained after starting rotation at 3 rpm is the initial gel strength. Record the initial gel strength (10-second gel) in pounds per 100 square feet.

7. Re-stir the drilling fluid sample at 600 rpm for 10 s and then allow the drilling fluid to stand undisturbed for 10 min. repeat the measurements as in 6 and report the maximum reading as the 10- minute gel in Pascal
Below is the picture of viscometer

Figure 3 Viscometer

3.6 Required tools

3.6.1 Equipments

1. Multi Mixer
2. FANN model 35
3. HTHP filter press
4. Electric Stability Meter
5. Basic equipment in lab such as beaker, separator funnel and thermometer

3.6.2 Consumables

1. Crude castor oil, Saline, Diesel
2. VERSATROL
3. VERSAPRO P/S
4. VERSAGEL HTHP
5. Lime
6. Brine (Water + $CaCl_2$)

3.7 Gantt chart

Table 6 Gantt chart for project implementation

ACTIVITIES	WEEK														
	1	2	3	4	5	6	7	Mid Semester Break	8	9	10	11	12	13	14
Getting The Mud Formulation done															
Acquire additive required - Castor Oil - Chemicals (Lime,Versatrol,VersaGel,VersaPro)															
Mud Formulation															
Conducting Tests -Rheology test -AHR HPHT Filter Press -Emulsion Stability test															
Submission of progress report															
Pre-SEDEX															
Final Report documentation															
Final Presentation															

3.8 Milestones

Table 7 Milestones

No.	Activities	Date
1	Complete methodology identification and base oil properties analysis	Week 4-6
2	Submission of Proposal Defense Report	Week 7
3	Proposal Defense (Oral presentation)	Week 9
5	Submission of Interim Draft Report	Week 14
6	Submission of Interim Report	Week 14
	Complete with determination of mud system formulation	Week 15
7	Complete acquiring the additives required	Week 17
8	Done with rheological properties, emulsion stability and filtration characteristics test on HPHT mud system	Week 25
10	Final report submission (draft)	Week 26
11	Final report submission	Week 27-28

CHAPTER 4

RESULT AND DISCUSSION

4.1 Rheology Test Results

The discovery of the new potential alternative will be proven through the laboratory work. The suitability of Castor oil as the continuous oil phase in drilling fluids during drilling operation can be determined from the output of the result analysis.

Table 5 consist the result of rheology test on Saraline oil based mud and castor oil based mud. Its shows the readings for Plastic viscosity, Yield point, Gel strength; Electrical stability and HTHP filter press From the table, T-1 until T-5 indicates the following;

Test 1 = Saraline Oil

Test 2 = Castor Oil

Test 3 = 60% Castor oil 40% Toluene

Test 4 = 40% Castor oil 60% Toluene

Test 5 = 20% Castor oil 80% Toluene

Table 8 Test Results

Products	T-1	T-2	T-3	T-4	T-5
600 rpm dial reading	60	300+	190	202	39
300 rpm dial reading	41	300+	117	144	26
200 rpm dial reading	22	-	89	121	21
100 rpm dial reading	16	-	60	99	16
6 rpm dial reading	9	-	23	67	10
3 rpm dial reading	7	-	25	64	10
Plastic viscosity, cP	19	-	97	58	13
Yield point, lb/100ft2	22	-	38	86	13
10" gel strength, lb/100ft2	10	-	24	62	11
10' gel strength, lb/100ft2	13	-	27	61	11
HTHP (500psi, 350 °F), ml	1.6	-	1.5	1.7	1.3
HTHP (Filter cake), mm	2	-	1.2	1.3	1.0
Electrical Stability	652	-	589	703	907

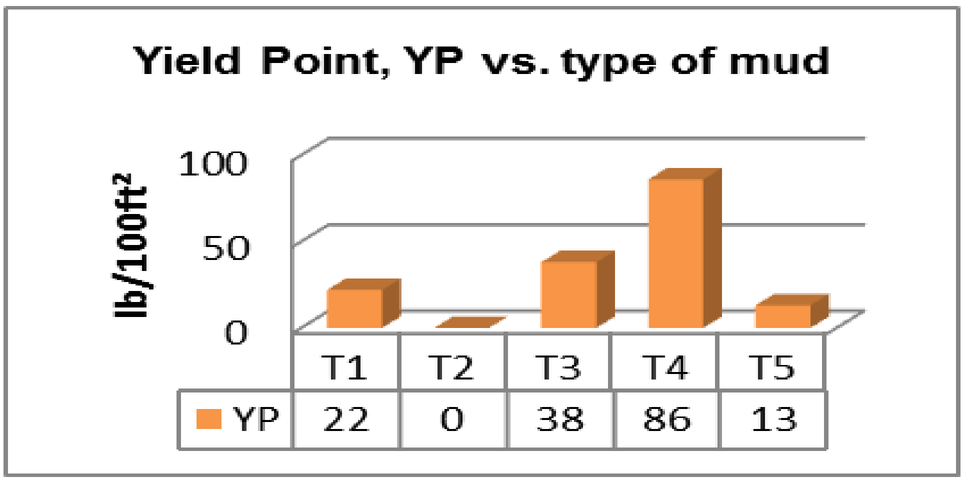

Figure 4 Graph of Yield Point vs. type of mud

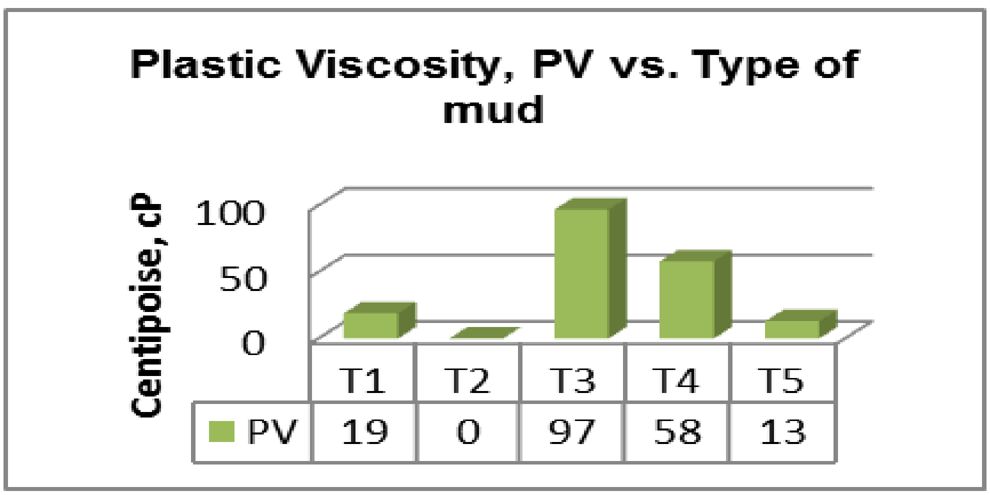

Figure 5 Graph of Plastic Viscosity vs. type of mud

Plastic viscosity relates to the resistance to flow due to interparticle friction. The friction is affected by the amount of solids in the mud, the size and shape of those solids and the viscosity of the continuous liquid phase. Figure 1 and 2 shows, the plastic viscosity (PV) and yield point (YP) for each tests. From the figures it can be seen that, the value of plastic viscosity (PV) and Yield point (YP) for castor oil are higher than Saraline oil base mud except for test 1(T-1) and test 5, (T-5).T-1 cannot shows invalid reading due to the use 100 percent castor oil. 100 percent castor oil will make the drilling fluid thicker, thus showing invalid reading. While, T-5 shows low PV and YP than T-3and T-4, this is due to the diluted castor oil. Approximately 184g of toluene is used in T-5 as the solvent in assisting castor oil dilution. The amount of toluene used is considered high for a dilution process. A good candidate for a drilling fluid is to have low PV but high YP. In oil-based mud, increase of YP can be cause by;

1. Drill solid – YP will be higher if high drill solid present
2. YP will be high in low temperature environment.

In oil base mud system, please keep in mind that emulsified water in oil base drilling fluid will act like a solid, and it will increase the PV dramatically.

If according to the assumption, castor oil seems like not suitable for base oil in drilling fluid but castor oil has the criteria of a based fluid. . Therefore, it can be treated further to be used commercially as a base fluid in drilling operation. More experiments and further tests should be conducted in order to determine the effectiveness of this castor oil as base oil in drilling fluids

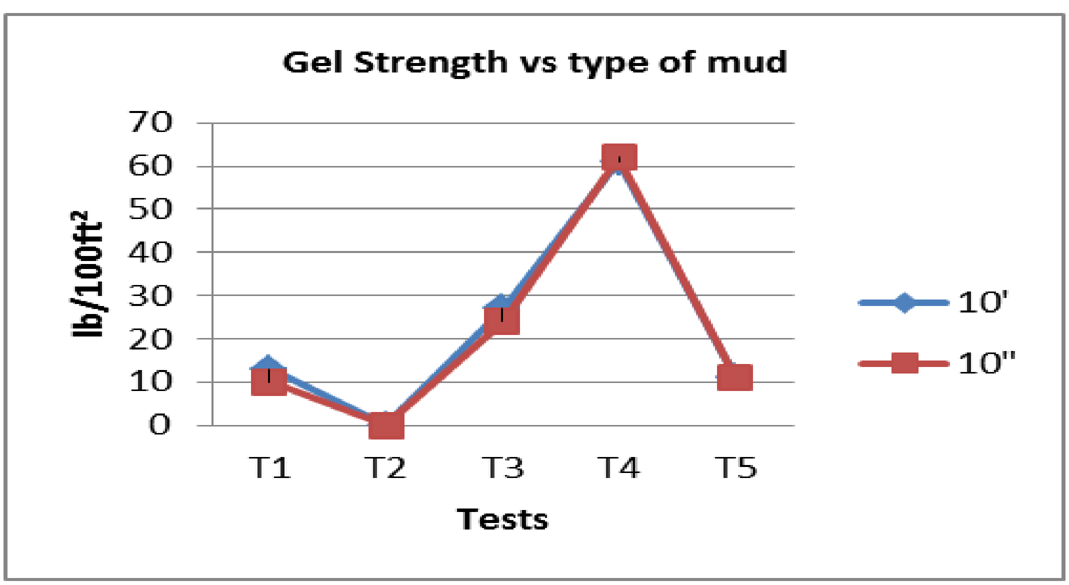

Figure 6 Graph of gel strength vs. type of mud

As for Gel Strength result, we can see that from figure 3, T-5 have the value of 13lb/100ft^2 for both times taken and it is the lowest value compared to the T-3 and T-4. This value is considered to be good since it is not too low and it is not too high. If the mud formulated has high gel strength, high pump pressure is required in order to break circulation after the mud is left static for a certain period of time (Jetjongjit, R. 2010). So, mud with low gel strength is much preferable. Thus from the graph mud from test 1 and test 5 are most likely preferable.

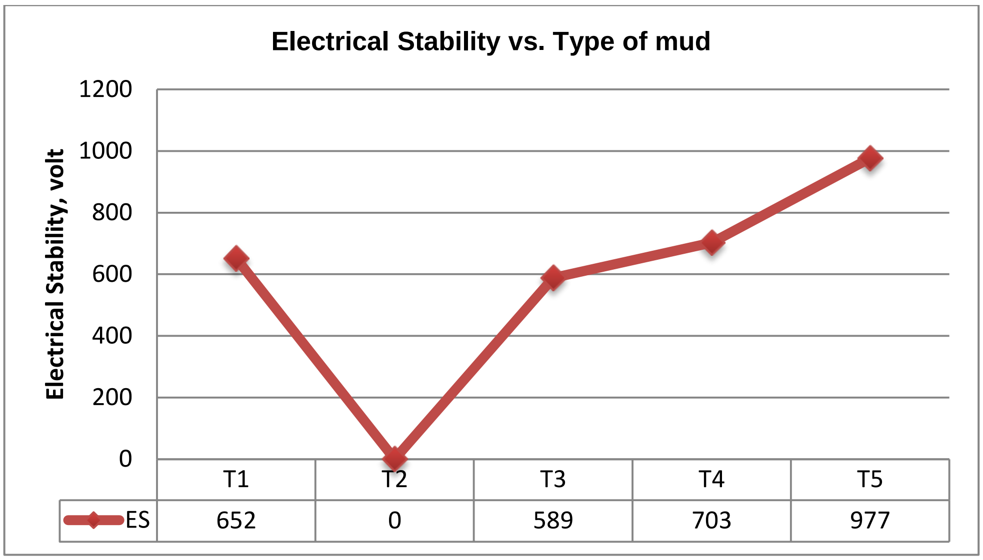

Figure 7 Electrical Stability vs. type of mud

Electrical stability (ES) is one of the vital properties of oil-based mud. It shows the voltage of the current flow in the mud. ES represents the number stability of the emulsion mud. A good emulsion mud will have high value of ES while on the other hand, if the emulsion is bad, the value of ES will be lower. This is because, oil based materials are not conductive. Therefore it will not transfer any power. Only water phase in the mud will conduct electricity. For high value of ES means that, the oil is totally dispersed inside the water leaving water outside. From the figure 4, the highest value of ES is for test 5 which is 977 and the lowest value (neglecting test 2) is from test 3 which is 589. The specification value is > 600 volt. (*SPE Drilling & Completion* 9, no. 1, 1994).

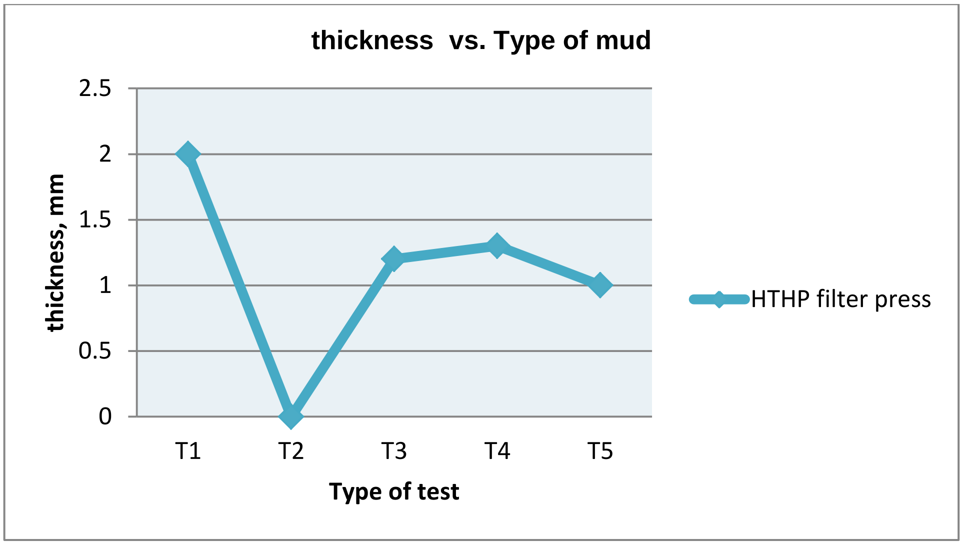

Figure 8 Filter cake thickness vs. type of mud

HTHP filter press test is conducted to determine the filtrate volume and filter cake thickness. From figure 5 it shows that the highest thickness was for Saraline oil based mud which is 2mm and the lowest are from T-5. Thickness of filter cake is an important factor as thick cake may cause problems in the wellbore for example, stuck pipe, high torque and etc. Thickness of filter can vary this due to the effect of fluid loss control agent. As for this experiment fluid control VERSATROL is being used.

From this experiment, it can be seen that the using mineral oil as base fluid is still the best because its shows better rheology result and other tests. The reason why mineral oil is far better compare to vegetable oil is Saraline is specially engineered to be used for commercial purpose in drilling fluid. Therefore, it definitely will show a most convincing result compared to the vegetable oil.

4.2 Economic Analysis

The cost of the drilling fluid is relatively small compared to the total cost of completing an oil well. Even though the cost it is small but choosing the right fluid and maintaining the right properties greatly influence the total well cost. Drilling can either cause lots of income or lots of losses; it is depend on every decision taken in the drilling and production processes. As for this project, castor oil is not suitable to be used as base fluid because of the price the oil and toluene. It can be considered expensive for a drilling fluid. This problem might be solved if new method of dilution is being used and production of castor is at lower cost.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion and recommendation

The aim of the project is to identify if castor oil is a good oil to be used as continuous phase in oil based mud and thus reduce the environmental problem caused by diesel oil based mud. The effectiveness of castor oil as a base fluid is achieved by comparison with conventionally used base oil.

Some points are clearly pointed out from the comparative study that covered physical characteristics.

1. Based on the rheology study, the PV of Saraline oil based mud is lower than the castor oil but addition of toluene minimized the gap.
2. High amount of toluene is being added in order to dilute the castor oil. Which may cause harm to human since toluene are poisonous chemical. Proper safety act should be done while using the chemical.

As for the recommendations in order to have better results, this project should use crude vegetable oil and not the vegetable oil that have being processed for commercial. This is because, crude vegetable oil have low water contain and this can reduce the emulsified water effect. Besides that, equipment and materials are also playing important role for a successful experiment. Reliable equipment should be used to reduce the human error and to get better results.

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APPENDIX 1

Castor Oil

Product : Castor Oil

CAS# : 8001-79-4

Synonym : Ricinoleic Acid 90%; Ricinus Oil

Formula : C57H101O6(OH)3

Class : Petrochemicals
Oils: Vegetable Oil and Fish Oil (Marine)
Oleochemicals: Fatty Acids, Fatty Alcohol & more
Essential Oils
Flavor and Fragrance Chemical Compounds
Personal Care - Cosmetic Ingredients
Drilling and Completion Fluids
Drilling Mud Lubricants
Drilling Mud Surfactants
Drilling Fluid Additives

Product Type :

Hazard :

Specifications

Appearance : colorless to pale brown clear oily liquid

Iodine Value : 83-88

Specific gravity : 0.95500 to 0.96100 @ 25.00 °C

Pounds/Gallon : 7.947 to 7.996

Refractive Index : 1.46200 to 1.47200 @ 20.00 °C

Boiling Point : 313.00 °C. @ 760.00 mm Hg

Acid Value : 2.00 max. KOH/g

Saponification Value : 176.00 to 185.00

Flash Point : 235.00 °F. TCC

Shelf Life : 24 month(s) or longer if stored properly

Storage : store in cool, dry place in tightly sealed containers, protected from heat and light

Odor : faint odor

APPENDIX 2

Recommended Practice for Field Testing of Oil-based Drilling Fluids

1 Scope

This Recommended Practice provides standard procedures for determining the following characteristics of oil-based drilling fluids:

a) drilling fluid density (mud weight);

b) viscosity and gel strength;

c) filtration;

d) oil, water and solids contents;

e) alkalinity, chloride content and calcium content;

f) electrical stability;

g) lime and calcium contents, calcium chloride and sodium chloride contents;

h) low-gravity solids and weighting material contents.

Annexes A, B, C, D, H, I, K and L provide additional test methods that may optionally be used for the determination of

i) shear strength,

j) oil and water contents from cuttings,

k) drilling fluid activity,

l) aniline point,

m) cuttings activity,

n) active sulfides,

o) PPA test method for cells with set screws,

p) PPA test method for cells with screw-on caps.

Annexes F, G and J provide procedures that may optionally be used for

q) sampling, inspection and rejection,

r) rig-site sampling,

APPENDIX 3

s) calibration and verification of glassware, thermometers, viscometers, retort kit cups and drilling fluid balances.

Annex E provides examples of calculations for

t) lime, salinity and solids content.

Annex M contains an example of a drilling fluid report form.

2 Terms and definitions

For the purposes of this Standard, the following term and definition applies:

2.1
ACS reagent grade
grade of chemical meeting the purity standards specified by the American Chemical Society (ACS)

2.2
API
American Petroleum Institute, 1220 L Street NW, Washington, DC 20005

2.3
CAS
Chemical Abstracting Service

2.4
USC
United States Customary unit, shown in parentheses following SI unit

3 Abbreviations

ACS	American Chemical Society
BAD	Base alkalinity demand
EDTA	eithylenediaminetetraacetic acid
ES	electrical stability
HT/HP	high temperature, high pressure
OCMA	Oilfield Chemical Manufacturer's Association
PNP	propylene glycol normal-propyl ether
PTFE	polytetrafluoreoethylene, brand name Teflon®
TC	to contain
TD	to deliver
R_{300}	viscometer reading at 300 r/min
R_{600}	viscometer reading at 600 r/min
[illegible]	static filtration rate

APPENDIX 4

m_1	mass of retort cup, lid and body with steel wool, g
m_2	mass of retort cup, lid, body and cuttings, g
m_3	mass of empty liquid receiver, g
m_4	mass of liquid receiver and fluid collected during solids analysis, g
m_5	mass of solids remaining in retort cup following solids analysis, g
R	static filtration rate
V	volume of liquid collected in receiver, ml
V_o	volume of oil, cm^3
V_s	volume of solids, cm^3
V_1	volume of filtrate after 7,5 min, cm^3
V_2	volume of filtrate after 30 min, cm^3
V_w	volume of water, cm^3
η_P	viscosity of plastic viscosity
η_Y	viscosity of yield point
η_A	appararent viscosity
φ_o	volume fraction of oil
φ_s	volume fraction of solids
φ_w	volume fraction of water
ρ	density
$\nabla\rho$	density gradient

4 Determination of drilling fluid density (mud weight)

4.1 Principle

A procedure is given for determining the mass of a given volume of liquid (= density). The density of drilling fluid is expressed as grams per cubic centimetre, kilograms per cubic metre, pounds per gallon or pounds per cubic foot.

4.2 Apparatus

a) Any **density-measuring instrument** having an accuracy of ± 0,01 g/cm^3, ± 10 kg/m^3, ± 0,1 lb/gal, or ± 0,5 lb/ft^3.

The mud balance is the instrument generally used for drilling fluid density determinations. The mud balance is designed such that the drilling fluid holding cup, at one end of the beam, is balanced by a fixed counterweight at the other end, with a sliding-weight rider free to move along a graduated scale. A level-bubble is mounted on the

APPENDIX5

Table 1 — Density conversions between SI and USC units

Grams per cubic centimetre[a] g/cm³	Kilograms per cubic metre kg/m³	Pounds per US gallon (lb/US gal)	Pounds per cubic foot (lb/ft³)
0,70	700	5,8	43,6
0,80	800	6,7	49,8
0,90	900	7,5	56,1
1,00	1 000	8,345[b]	62,3
1,10	1 100	9,2	68,5
1,20	1 200	10,0	74,8
1,30	1 300	10,9	81,0
1,40	1 400	11,7	87,2
1,50	1 500	12,5	93,5
1,60	1 600	13,4	99,7
1,70	1 700	14,2	105,9
1,80	1 800	15,0	112,1
1,90	1 900	15,9	118,4
2,00	2 000	16,7	124,6
2,10	2 100	17,5	130,8
2,20	2 200	18,4	137,1
2,30	2 300	19,2	143,3
2,40	2 400	20,0	149,5
2,50	2 500	20,9	155,8
2,60	2 600	21,7	162,0
2,70	2 700	22,5	168,2
2,80	2 800	23,4	174,4
2,90	2 900	24,2	180,7

[a] Same value as relative density.
[b] Accurate conversion factor.

5 Alternative method for determination of drilling fluid density

5.1 Principle

5.1.1 The pressurized mud balance provides a more accurate method for determining the density of a drilling fluid containing entrained air or gas than does the conventional mud balance. The pressurized mud balance is similar in operation to the conventional mud balance, the difference being that the slurry sample is placed in a fixed-volume sample cup under pressure.

5.1.2 The purpose of placing the sample under pressure is to minimize the effect of entrained air or gas upon slurry density measurements. By pressurizing the sample cup, any entrained air or gas is decreased to a negligible volume, thus providing a slurry density measurement more closely in agreement with that obtained under downhole conditions.