ABSTRACT

One of the main functions of drilling mud is to lubricate the wellbore. Lubrication in wellbore during drilling operation are very important to avoid the drill strings in contact with the wellbore formation. If the drill string surface is in contact with the surface of wellbore formation, friction will occur and hence it can lead to wear of tools. The conventional oil based muds used in the industries nowadays have a lot of disadvantages such as expensive and pollute the environment. As an alternative, the Jatropha oil is introduced to make oil based mud that is cheaper and more environmental-friendly. The lubricity of Jatropha oil drilling mud was investigated using Multispecimen Wear Tester (MWT) which the equipment will simulates the friction between the rotations of drill string and the wellbore formation. The Multispecimen Wear Tester is used to get the coefficient of friction of Jatropha oil based mud. The result shows the Jatropha oil based mud have a high lubricity compared to the Saraline oil based mud. However, the rheology properties of the Jatropha oil based mud are not suitable to be used in the industry without being diluted because it has high value of plastic viscosity and yield point.

ACKNOWLEDGEMENTS

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF STUDY

Drilling fluid is one of the main components in drilling operations. One of the important properties of drilling mud is to able to lubricate the drill bits, drill strings and wellbore formation. This lubrication is important because, if the drilling mud cannot lubricate properly or effectively, the torque and drag force exerted on the equipment will become higher. This increasing of forces will create a lot of problems to the drilling equipment and drilling operations. The main effect of the lubricity ineffectiveness in a drilling operation is the drill string will be exposed to wear. This is because, when the drill strings surface is in contact with the wellbore formation without lubrication, the equipment will wear quickly as the drilling process is a continuous and repetitive action.

Besides that, the other effect of lubricity ineffectiveness in a drilling operation is the drilling process will become difficult and ineffective. When the drag force exerted on the drilling equipment is high, the torque force required to counter the drag force also must be high. If the torque force is low, the drilling parameters such as rate of penetration also will decrease.

Nowadays, the usage of oil based mud (OBM) is widely used compare to water based mud (WBM) to counter various problems while drilling a well. Furthermore, with advances in drilling technologies over 30 years, horizontal and multilateral wells have become a primary design type to develop reservoirs, especially in unconventional resources. The demand for high pressure high temperature (HPHT) well also increases as the demand for new exploration well increases. The most common practices to drill a HPHT well is by using OBM as the drilling mud because it have more advantages compare to the WBM such as high thermal stability and high resistivity. However, OBM is not suitable to be used in the offshore because it can pollute the environment.

The need to produce efficient, economical and environmental-friendly drilling operation has promoted the development of new OBM to replace the conventional OBM. The new formulations for an environmental-friendly OBM are using biodiesel as their base oil to replace the petroleum based oil. One of the examples of biodiesel oil that can be used in preparing the drilling mud is Jatropha oil. The Jatropha oil based mud (JOBM) is suitable to be used in drilling operation because it exhibits similar properties as the diesel oil in drilling mud but more environmental-friendly. However, the research on the rheology and the lubrication properties of the JOBM are needed to be done to study the effect of using JOBM as a lubricator in drilling operation. This research is mainly focus on the lubrication properties of the JOBM and it is needed to be done because a good lubricity drilling mud can improve the effectiveness of drilling process and reduce the cost.

1.2 PROBLEM STATEMENT

One of the functions of the drilling mud is to lubricate the hole during drilling operation. If the wellbore and the drill string are not lubricated with a good lubrication, the torque and drag force exert on the drill string will become higher and hence can create problems. In order to counter these problems, a conventional oil based mud using petroleum based oil such as diesel and Saraline has been introduced to the industry. However, the conventional oil based mud have a lot of disadvantages such as it can pollute the environment and expensive. As an alternative, the conventional oil drilling mud can be replaced with biodiesel drilling mud to minimize it effects to the environment such as Jatropha oil. However, there is no study about the lubrication of Jatropha oil in drilling mud has been made in past year. So, proper assessment is needed to be done to study the lubricity properties of oil based mud using Jatropha Oil.

1.3 OBJECTIVE

The main objective of this research is:

- To study the lubricity of Jatropha oil based mud (JOBM) and its effects on the drill string and wellbore formation during drilling operations by determining the coefficient of friction and its wear effects using Multispecimen Wear Tester (MWT).

The other objectives of this research are:

- To prepare the oil based mud using Jatropha oil
- To study the mud rheology of the formulated JOBM used in this research

1.4 SCOPE OF STUDY

The study is mainly focus on the Jatropha Oil Based Mud used as the lubricant in the drilling operations. The friction coefficient of the JOBM can be obtained using Multispecimen Wear Tester. The MWT will be used throughout the experiment with varies viscosity of JOBM. Besides, the study also focuses on the effects of using JOBM as lubricator on drill strings and wellbore formation. The topography and the tribology of the equipments and formation will be observed thoroughly in this research.

CHAPTER 2
LITERATURE REVIEW

2.1 LUBRICATION

Lubrication is the process to reduce the friction and wear between two opposing surfaces of the components by using a substance called lubricant. Lubrication can be defined as the effect of a third body on the contacting bodies. The lubricant will act as a film that protects two bodies from contacting each other. The thickness of the film is greatly dependent on the lubricant viscosity at both high and low temperatures. In general, the coefficient of friction in the presence of lubrication is reduced so that $0.001 < \mu < 0.1$.

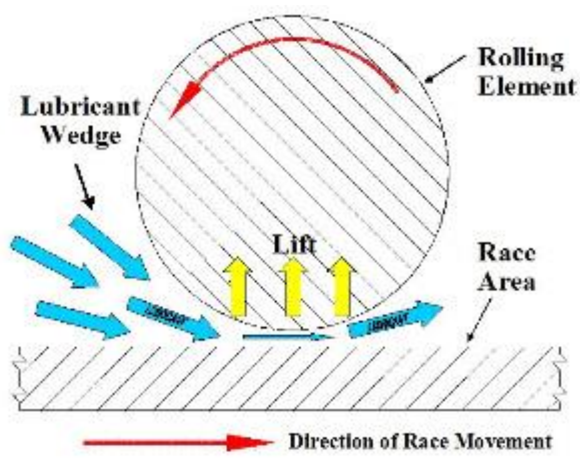


FIGURE 1: Lubricant Mechanism, Alternative Energy Resources (n.d.)

The friction and wear are needed to reduce because it can give a lot of effects to the components and operations. Friction force is the resistance force encountered by one body in moving over another when subjected to applied normal load. As the result of the resistance between the moving bodies, a force is generated that is known as friction force. From the figure below, the force F_3 is the friction or drag force exerted on body as the body slide down due to gravity force, F_1.

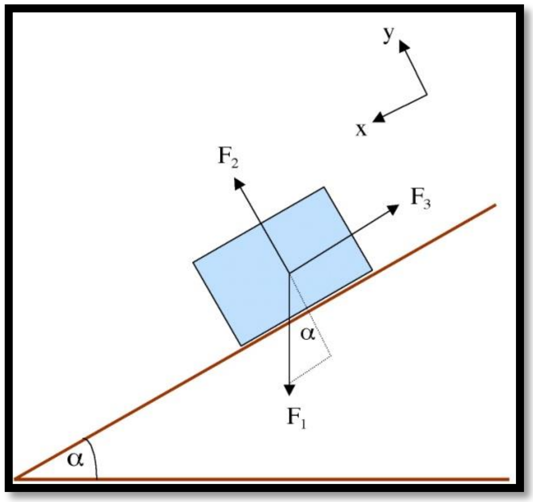


FIGURE 2 : Friction Force Free Body Diagram

If the friction force is allowed to occur continuously, a wear to the components will occur. The severity of the wear are depending the coefficient of the friction between the two bodies. In order to ensure a good lubrication, a good lubricant must possess the following characteristics:

i. High boiling point.
ii. Low freezing point.
iii. High viscosity index.
iv. Thermal stability.
v. Corrosion prevention.
vi. High resistance to oxidation.

In order to estimate the value of the friction, the coefficient of friction of the materials is needed to be calculated. The coefficient of friction can be defined as the static force of the body over the normal force exerted on the body. There are two types of coefficient of friction which are coefficient of static and kinetic friction which is μs and μk respectively. Below is the formula of the coefficient of friction.

$$Coefficient\ friction, \mu = \frac{Static\ force, Fs}{Normal\ force, Fn}$$

2.2 DRILLING MUD AS LUBRICANT

Drilling mud is very important in drilling. Besides its main function to control the wellbore pressure in the well, it also functioning to lubricate the drill string with the wellbore formation. In this research, the coefficient of kinetic friction will be studied because in the drilling operations, there are sliding movements between drill string and wellbore formation. These sliding movements will make the friction forces or also known as drag force exerted on the drill string. According to Mitchell & Samuel (2007), drag is a force that is attributed to friction generated by drill string contact with the wellbore. This friction will reduce the surface torque transmitted to the bit when it rotates. Figure below shows the friction force exerted on the drill string when the drill string is in contact with the wellbore formation.

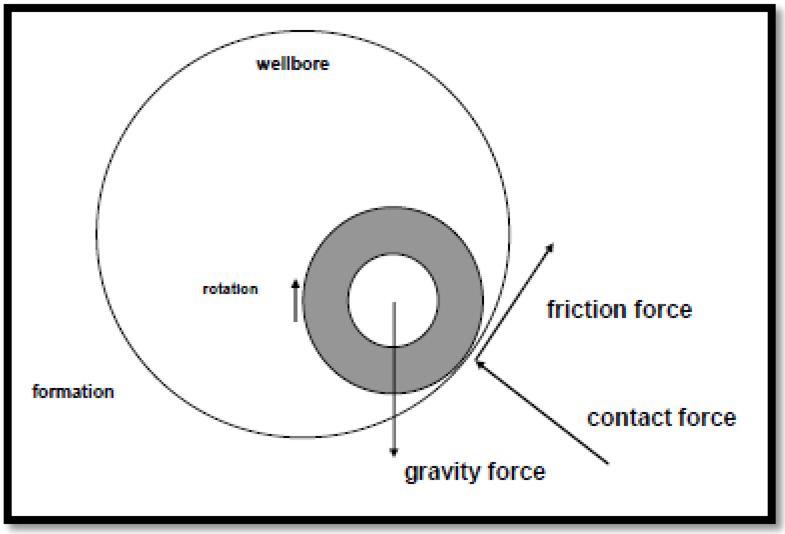


FIGURE 3: Friction in the Wellbore

In drilling, the frictions are needed to be reduced because it can lead to a wear in the drilling equipments such as drill bits, drill strings and casing. A lubricant which is the drilling mud is used in drilling operations to reduce the torque and drag of drill string and drill bit with the formations. According to Kercheville and Hunds (1986), drilling mud lubricity are primarily involved the rubbing of drill pipe and bits against the borehole and casing during rotation and tripping. By using the drilling mud in drilling operation, it will reduce the friction and hence reduce wear on the equipment.

2.3 JATROPHA OIL

Jatropha oil is biodiesel oil extracted from the fruit of Jatropha plant. According to Anand et al. (2011), *Jatropha curcus* (Linnaeus) is a multipurpose bush/small tree belonging to the family of Euphorbiaceae. The name *Jatropha curcus* is derived from a Greek word “Jatros” meaning “Doctor” “and trophe” meaning ‘nutrition’ because of the potential of this plant for medicinal purposes . Jatropha can grow in various types of soil and weather. According to Fosfa Newsletter, Jatropha plants can grow in many types of soil such as gravelly, sandy, saline and loamy soil with adequate nutrient content. Jatropha is a highly adaptable species and this characteristic can make the plant survive through a drought season even though it only receive small amount of water. Annually, the plant can be harvested for two or three times per year and it can produce seeds until 30 years.

The Jatropha plants are well known around the world for its usage. It has a lot of usage. It can be used as a medicine for malaria treatment and high fevers, used to make soap and candles, high quality organic fertilizer and biomass feedstock to power electricity plants. Besides that, the main use of Jatropha plant is the oil extracted from its seed. One of the Jatropha family, Jatropha curcas has seeds that can produce high biofuel or biodiesel oil. Kizilov (2009) stated that one Jatropha curcas fruit are able to produce seeds with an oil content of 37% - 64% from its weight.

This renewable fuel can be as a diesel substitutes because the biodiesel have similar properties to diesel fuel. It contains less sulfur content and can be used in diesel engines without major engine modifications (Ramesh et al. 2006). According to Adebowale and Adedire (2006), the Jatropha oil has a specific gravity of 0.9186 and viscosity of 50.73 cs. This high value of kinematics viscosity is suitable to be used in the lubrication materials as one of the properties of good lubricator is have a high kinematic viscosity. Furthermore, the Jatropha oil also contained a higher concentration of unsaturated fatty acids than the saturated ones. The physical and chemical analysis of the Jatropha oil compared to the chemical analysis of standard diesel oil is shown on the Table 1 below.

TABLE 1: The Physical and Chemical Analysis of Jatropha Oil, Adebowale and Adedire (2006)

Composition	Percentage
Palmitic acid (C16:0)	11.3
Stearic acid (C18:0)	17.0
Oleic acid (C18:1)	12.8
Linoleic cid (C18:2)	47.3
Arachidic acid (C20:0)	4.7
Arachidoleic acid (C20:1)	1.8
Behenic acid (C22:0)	0.6
C24:0	44

Composition	Percentage
Colour	Golden Yellow
Specific gravity	0.8601
Refractive index	1.4735
Free fatty acids (%)	4.54
Acid value (mg. KOH. g^{-1})	4.24
Saponification value (mg.KOH.g^{-1})	169.9
Iodine value (mg. I_2. g^{-1})	111.6
Peroxide value (mg reac.O_2 g^{-1})	3.5

TABLE 2: Characteristics of Jatropha Curcas Biodiesel and Comparison with Diesel, Francis et al. (2005)

Specification	Standard specification of *Jatropha* oil	Standard specification of Diesel
Specific gravity	0.9186	0.82/0.84
Flash point	240/110 °C	50 °C
Carbon residue	0.64	0.15 or less
Cetane value	51.0	50.0 up
Distillation point	295 °C	350 °C
Kinematics Viscosity	50.73 cs	2.7 cs up
Sulpher %	0.13 %	1.2 % or less
Calorific value	9 470 kcal/kg	10 170kcal/kg
Pour point	8 °C	10 °C
Colour	4.0	4 or less

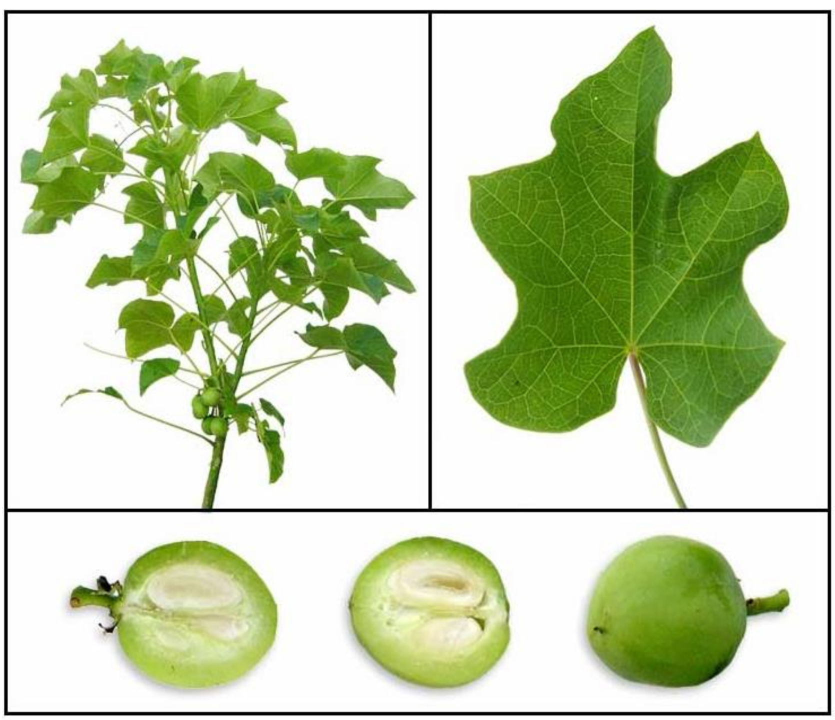


FIGURE 4: Jatropha Plant and Seed, Intelligentsia International Inc. (2008)

2.4 JATROPHA AS LUBRICANT

Nowadays, almost every type of lubricant used in the industries is made from petroleum. However, petroleum-based lubricants also contribute to the pollution of the environment. In order to reduce the environmental effects of the existing lubricant products, new alternative of lubricants which is made from biodiesel were introduced to the market. Based on the research by Tlydsley (1979), the lubricating properties of vegetable oil-based materials are well established. The vegetable oils can overcome the problems of toxicity and flash point inherent in normal hydrocarbon based materials such as diesel oil. According to Hu J. et.al (2004) also, the biodiesel have a good lubricity because of the fatty acid methyl esters and monoglycerides in their content and free fatty acids and diglycerides also affected them slightly, while triglycerides almost had no effects at all.

One of the types of biediesel that are suitable to be used as lubricants is Jatropha oil. According to Resul et. al (2011), Jatropha curcas has great potential as feedstock for producing biodegradable lubricants. It is also concluded that the viscosities and pour point of Jatropha bio lubricant are comparable to replace the petroleum based lubricant product.

2.5 JATROPHA OIL BASED MUD (JOBM)

Nowadays, Oil based mud (OBM) are widely used to drill a well. Many drilling companies used OBM because it has some advantages to tackle well control problems in drilling certain type of formations especially for HPHT well compared to water based mud. Research by Fisk and Jamison (1989) shows that increasing the temperature can change the rheology properties of the drilling mud and OBM is more suitable to be used in HPHT well because it has thermal stability. However the usage of OBM also can brings negative effects to environment and drilling operation. According to Galate (1986), the main disadvantage of conventional OBM is the toxicity properties of the oil used in drilling mud. The toxicity of the oil used in the drilling mud can pollute the environment if it not disposed correctly. In offshore applications, tighter environmental regulations are forcing the transport of diesel-based oils to shore in order to prevent pollution and it is quite costly to transport and dispose it. So in order to reduce the pollution and hence reduce the cost, a diesel based drilling mud can be replace with a biodiesel oil that are contain less toxicity substances.

Jatropha oil can be used as one of the alternative in producing the drilling mud for drilling operations. Since the properties of the Jatropha oil are more likely as diesel oil, the Jatropha oil can replace the diesel oil to produce a biodiesel drilling mud. This non edible vegetable oil is less toxicity compared to petroleum based oil. It also can behave as oil based drilling mud like the conventional OBM. According to Adesina et al. (2012), a research on the environmental impact evaluation of a safe drilling mud to investigate the rheological properties of JOBM and its impact on environment compared to conventional OBM. The findings of their research are the Jatropha based mud has a lower viscosity, that is has less resistance to flow and lower pressure loss. Besides that, the toxicity test of the JOBM also shows it is safer and less harmful to the environment compared to conventional OBM. Furthermore, based on the research made by Kizilov (2009), the Jatropha Oil Based Mud (JOBM) could indeed be used as alternative drilling mud which requires less chemical additives, cheap and environmentally safe, comparable to the other drilling mud. The JOBM requires less chemical additive in order to meet the standard requirements for the drilling mud.

CHAPTER 3
METHODOLOGY

3.1 RESEARCH METHODOLOGY

The main objective of this research is to study the lubricity of Jatropha Oil Based Mud by conducting various experiments and researches. In order to gain more understanding before conducting the experiments, a case studies research has been made by reading journals, books and technical papers about the lubrication of drilling mud using Jatropha oil. These references will be used throughout the research as a guidance to obtain accurate results.

The experiments in this research can be divided in four sections which are the material preparation, Jatropha oil based mud preparation, Multispecimen Wear Tester experiment and wear analysis experiment.

3.1.1 Material Preparation

The first section of the experiments is the material preparation. The most important material to be used in this research is Jatropha oil. In order to complete the research, the author obtained the Jatropha oil from Bionas Sdn. Bhd. the company processed the Jatropha in the form of crude Jatropha oil. In this project also, a few modifications on the existing MWT components such as the pin and rotating disk need to be done because the materials used in this project differ from the existing tribology test. Besides that, the chemical analysis of Jatropha oil also need to be done in order to gain more understanding the lubricity of Jatropha oil. Below are the methodologies to prepare the material.

3.1.1.1 Pin

The objectives of this research are to find the value of friction and wear of drill string in the wellbore by using Jatropha oil based mud. For this experiment, the drill string will be in pin form, and it’s in cylinder shape, with dimension of 4mm diameter and 12mm height. The material used for the pin is mill steel.

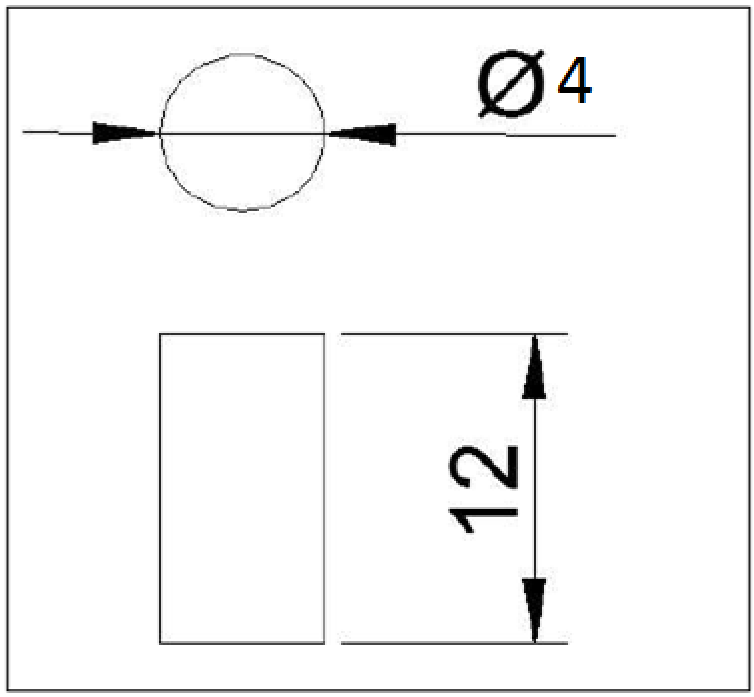


FIGURE 5 : Drawing for Pin

FIGURE 6 : Pin

FIGURE 7 : Plan View of the Pin

In order to hold the pin during the experiments, a pin holder is required to hold the pin. The pin holder used in this research is already available in the laboratory. So, there is no need to fabricate a new pin holder since the pin holder in the laboratory can fit together with the pin.

FIGURE 8: Pin Holder

3.1.1.2 Granite Disk Plate

In order to study the friction between the wellbore and the drill string, a disc plate made of granite is need to be used to simulate the actual actions that happened on the wellbore by using mutispecimen wear tester. The disc that is being used is the Granite rock which contains quartz, feldspar, mica, and iron ore. The granite is cut into disc form with dimension of 52mm diameter, and 2mm thick. The disc is prepared by using the machine that is provided in the Geology Lab at building 15, Universiti Teknologi PETRONAS.

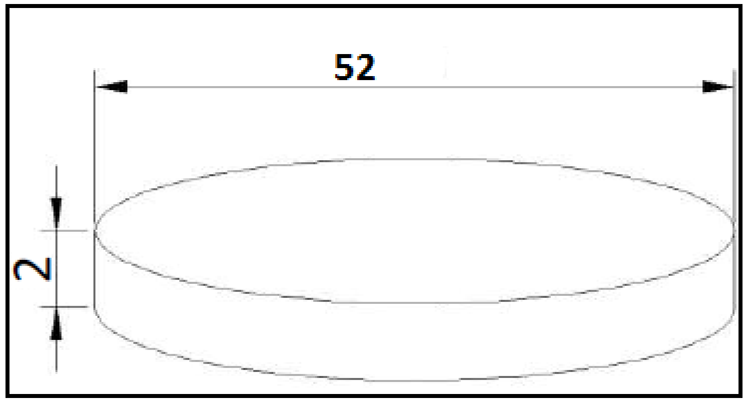


FIGURE 9 : Drawing of Disc Plate

FIGURE 10 : Granite Disc Plate

3.1.1.3 Drilling Fluid Cup

The drilling fluid cup is a component that will be used to hold the disc and the drilling fluid. Its function is to ensure the disc to be merging into the drilling fluid, and also to ensure the area of contact between the pin and the disc to be lubricated all the time. At the side of the component, there are 4 holes with Screw size of M2. The function of the screw is to tighten up the disc in place, so that it will not move together with the pin during the experiment is done.

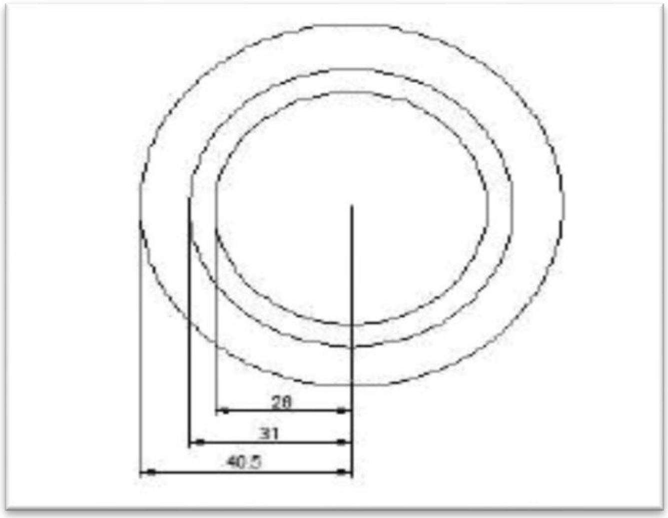


FIGURE 11 : Plan View of Disc Cup

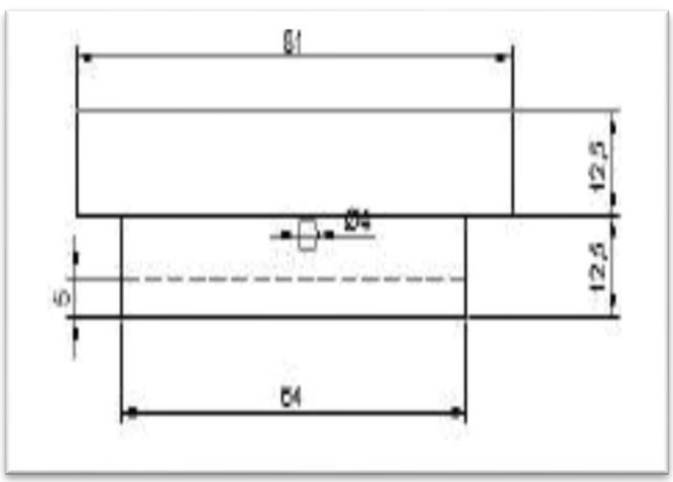


FIGURE 12 : Side View of Disc Cup

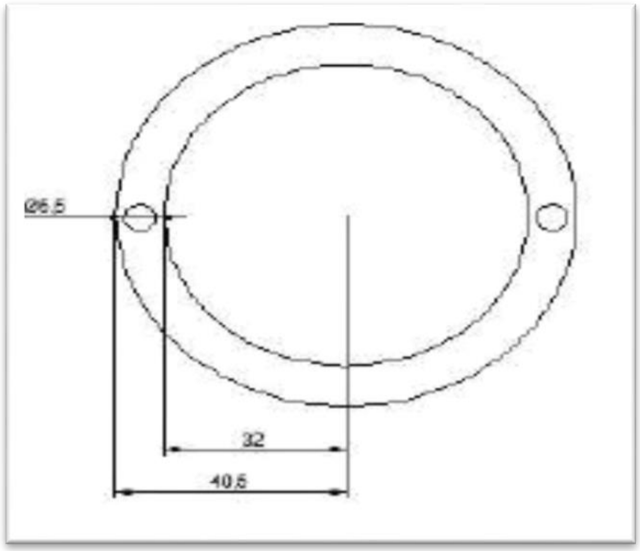


FIGURE 13 : Bottom view of Disc Plate

FIGURE 14: Disc Cup

3.1.2. Jatropha Oil Based Mud Preparation

The second section of the experiments is to prepare the oil based mud using Jatropha oil. The JOBM will be prepared in the Drilling Laboratory at block 15 in Univesiti Teknologi PETRONAS. In mud preparation process, the rheology properties of the JOBM such as the density, viscosity, gel strength and yield strength will be examined and tested. The tools that will be used in this experiment are mud balance, Marsh funnel and FANN Viscometer. The JOBM will be prepared according to the standard which has stipulated in American Petroleum Institute - API 13B-2; Recommended Practice Standard Procedure for Testing Oil-Based Drilling Fluid. The oil-water ratio was set at 75:25. The amounts of the materials (formulation) needed for preparing the JOBM are:

TABLE 3: Drilling Mud Formulations

PRODUCTS	SG	SARALINE	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	TEST 6	TEST 7
Jatropha	0.923		188.7	150.696	131.859	113.022	94.185	75.348	56.51
Saraline	0.77	155.16							
Toluene				37.674	56.511	75.348	94.185	113.622	131.86
Confi-Mul P	0.95	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Confi-Mul S	0.96	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Confi-Gel	1.70	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Confi-Trol	1.05	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Lime	2.30	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Fresh Water	1.00	66.85	68.03	68.03	68.03	68.03	68.03	68.03	68.03
Calcium Chloride	3.49	24.22	24.65	24.65	24.65	24.65	24.65	24.65	24.65
Drill-Bar	4.39	231.49	188.15	188.15	188.15	188.15	188.15	188.15	188.15

Remarks :

Test 1 : Jatropha oil 100%

Test 2 : Jatropha oil 80%

: Toluene 20%

Test 3 : Jatropha oil 70%

:Toluene 30%

Test 4 : Jatropha oil 60%

:Toluene 40%

Test 5 : Jatropha oil 50%

:Toluene 50%

Test 6 : Jatropha oil 40%

:Toluene 60%

Test 7 : Jatropha oil 30%

:Toluene 70%

Below are the procedures to examine the rheology of the drilling mud.

3.1.2.1 Mud Mixing

1. The following materials above were prepared first.
2. Crude Jatropha oil and Toluene were mixed first with magnetic stirrer for 4 minutes.
3. Confi-Mul P and Confi-Mul S were mixed in mud mixer for 5 minutes.
4. Confi-Gel was added slowly and mixed for another 2 minutes.
5. Confi-Trol was added slowly and mixed for another 2 minutes
6. Lime was added slowly and mixed for another 15 minutes.
7. Calcium chloride with fresh water is added slowly and mixed for another 2 minutes.
8. Barite was added slowly and mixed for another 30 minutes.

3.1.2.2 Mud Weight or Density Test

1. The mud weight test will be using typical mud balance.
2. The lid from the cup is removed and completely fills the cup with the mud to be tested.
3. The lid is replaced and rotated until firmly seated; make sure some mud is expelled through the hole in the cup.
4. The mud is washed or wiped from outside the cup.
5. The balance arm is placed on the base, with knife edge resting on the fulcrum.
6. The rider is moved until the graduated arm is level, as indicated by the level vial on the beam.
7. At the left hand edge of the rider, the density is read on either side of the lever in all desired units without disturbing the rider.

3.1.2.3 Viscosity

1. Viscosity will be measured using FANN Viscometer.
2. A recently agitated sample in the cup is placed, the upper housing of the viscometer is tilted back, the cup is located under the sleeve and the upper housing is lowered to its normal position.
3. The knurled knob is turned between the rear support posts to raise or lower the rotor sleeve until it is immersed in the sample to the scribed line.
4. Stir the sample for about 5 seconds at 600 rpm, and then select the RPM desired for the best.
5. Wait for the dial reading to stabilize.
6. Record the dial reading and RPM.

3.1.2.4 Gel Strength

1. Stir the sample at 600 rpm for about 15 seconds.
2. Turn the RPM knob to stop position.
3. Wait the desired time rest time.
4. Switch the RPM knob to GEL position.
5. Record the maximum deflection recorded on the dial.

3.1.3 Multispecimen Wear Tester Experiment

The third section of the experiment is to study the lubrication of the JOBM using Multispecimen Wear Tester (MWT). The WMT is a machine that is used to test various kinds of tribology properties such as friction and wearing behavior. In order to test the lubricity of the JOBM, the WMT rig will be set as follows:

- The pin on top of the WMT is constructed using steel. This pin represents the drill string.
- The small disc that is made from granite will be placed at the bottom of the WMT. This disc represents the wellbore formation of the well.

The prepared JOBM will be poured in the space between the pin and the disc. The JOBM will act as the lubricator to reduce the friction between the pin and the disc. Below are the procedures to test the lubricity of JOBM.

1. Data recording will be done using computer connected to the rig. The RPM, disc, pressure, force are constants. For trial, the data used was:

   Rotational speed – 120 rpm
   Applied load – 10N
   Time –30 minutes per run
   Disc Plate – Granite
2. First, the disc plate will be weighed to get the initial weight before the experiment. The weight taken should be accurate, with at least 4 decimal places, as the expected wearing behaviour to be small.
3. Then, the pin will also need to be weighed. Same as the disc, the accuracy of the weight recorded should be at least 4 decimal places.
4. The initial weight of both disc and pin will be used later in the result part to calculate, and get the wearing activity that happen on these two contact surfaces; in gram.

5. As for the pin, make sure there is no oil/fluid on it. Any other fluid will affect the experiment's result. To solve this, the pin is clean up the surface of the pin with methanol, and dries it up with dry cloth.
6. After that, install the pin into the holder by placing the pin inside the holder, and tighten up with the screw inside the holder. The pin must be tight enough so that no rotation of pin within, inside the holder will occur. Then, install the holder inside the MWT.
7. On the other side, the disc plate will be put into the drilling fluid cup. The disc is put into the cup, and tighten up so that no rotation of the disc to occur; disc stay still, fix position. After tighten up, drilling fluid will be filled into the cup, until the disc is submerged into the fluid. Then, place the cup into the rig.

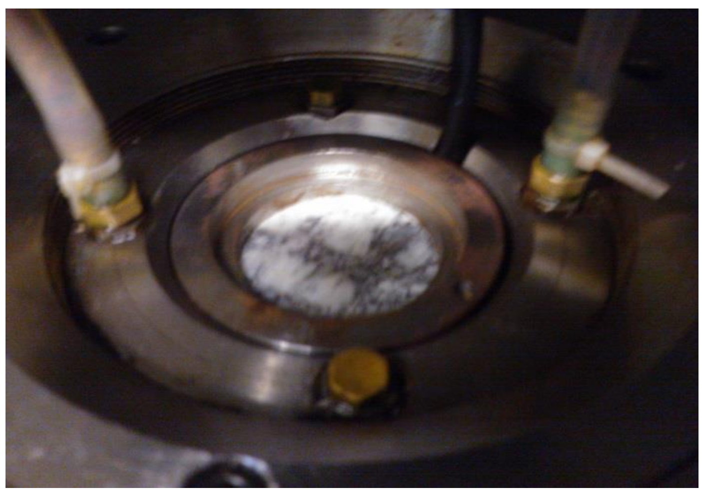


FIGURE 15 : Drilling Fluid Cup on MWT

8. After set up all the components inside the rig, set up in the software will be done. Using the software, the parameters for rotational speed, time taken and others are keyed in through the computer.
9. Then, the load will start to be put on to the lever. The first load will only be used for the pin and the disc to be in contact; no applied load. As this is only used to let the contact between the pin and disc occur, only small load will be put onto the lever. At the same time, the applied load in the software will be set to zero.

FIGURE 16: MWT Lever

10. Only by then, the applied load will be loaded. Based on Figure 16, there are 2 places to place the load. The ratio of the lever is 2:6. Means, if you put 5N load on the left, it will time 2, and if you put on the right place, it will time by 6. That's how the applied load on this MWT works. As for this experiment, 5N load is placed on the left place.
11. Then, the experiment is started by clicking start in the software. Through the software, the graph of the experiment is plotted, and the trend of the experiment can be observed.
12. When the experiment ended, take out the disc, as well as the pin from the rig and also from their holder/cup.
13. The pin will then be weighed to find the final weight, after the experiment. But as for the disc, it will need to be left for one day in order to dry it up and remove all drilling fluid inside the granite disc. This is to ensure that the final weight recorded will have the same condition as the initial weight; dry weight.
14. Data for the calculation of volume loss is acquired from the worn region of the sample and from the intact region around it. A reference plane is constructed for the intact surface. Volume loss is calculated from the differences between the interpolated reference plane and the actual worn surface.

15. The entire step above is repeated by replacing the drilling mud sample with another drilling mud.

FIGURE 17: Multispecimen Wear Tester

3.1.4 Wear Analysis Experiment

The last experiment that will be done is to study the effect of frictions and wear on the wellbore formation and drill strings by observing the surface of the granite disc after MWT experiment. Besides that, the wear also can be identified by calculating the difference in weight value of the pin before and after MWT experiment.

3.2 Project Work

PRELIMINARY RESEARCH

- Study on research paper
- Understand the concept and theory

MUD PREPARATION AND TEST

- Finding suitable material (Jatropha Oil)
- Perform rheology test

FRICTION TEST

- Pin and disk plate preparation
- Multispecimen Wear Tester Experiment

TOPOGRAPHY

- Pin and disk plate preparation
- Wear Analysis

DISCUSSION

- Discuss the findings and results
- Compile all the related result and produce in hardcopy and softcopy form

3.1 Gantt Chart and Milestone for FYP 1

	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Topic Selection							MID SEM BREAK									
2	Preliminary Research Work																
3	Submission of Extended Proposal																
4	Proposal Defense																
5	Material Preparation																
7	Submission of Interim Draft Report																
8	Submission of Interim Report																

Important Dates

Key Milestone

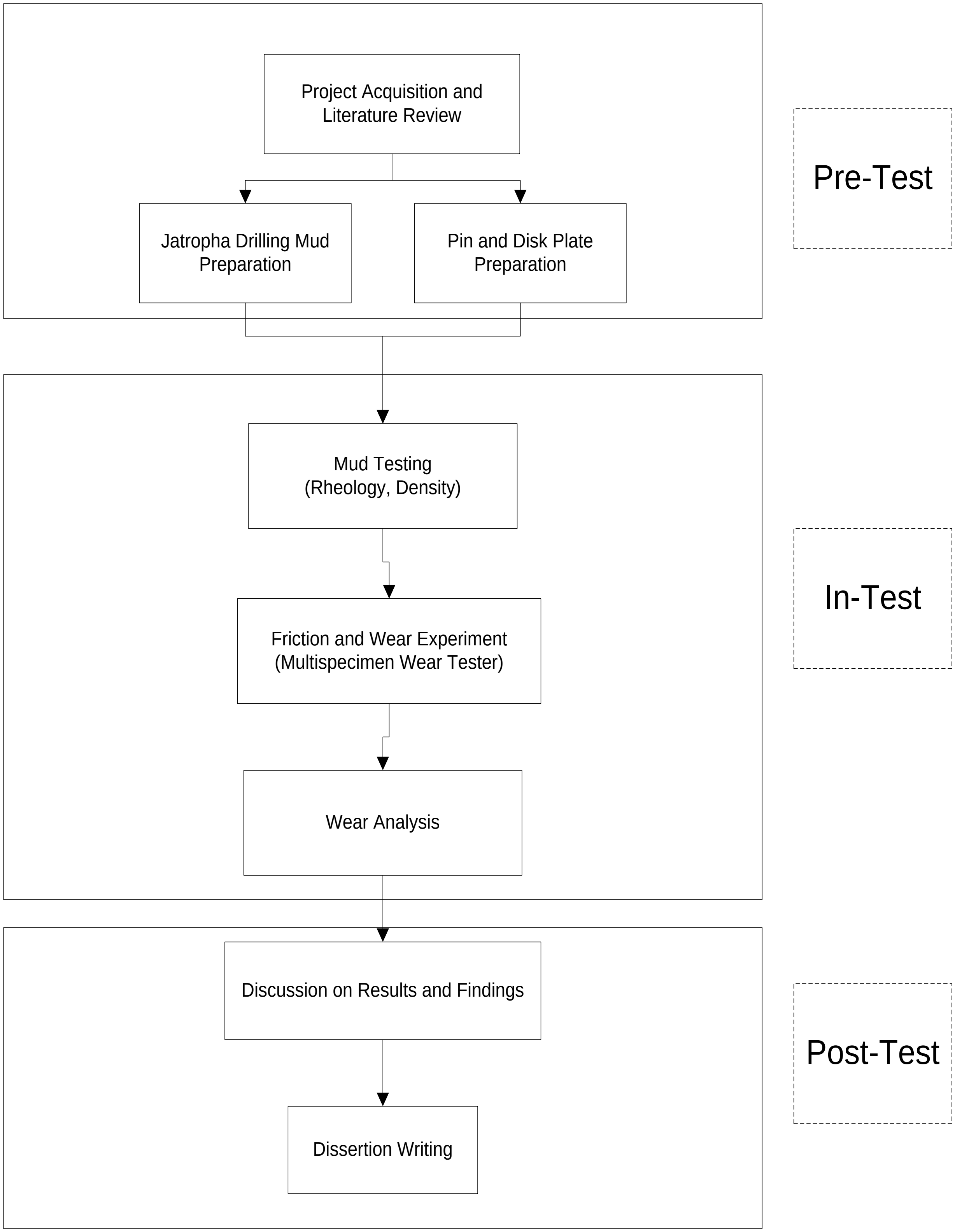
Gantt Chart and Milestone for FYP 2

	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Granite Preparation							MID SEM BREAK									
2	Mud preparation																
3	Mud Testing																
4	Submission of Progress Report																
5	Friction Test																
6	Wear Analysis																
7	Pre Sedex																
8	Technical Paper																
9	Oral Presentation																
10	HardBound Submission																

Important Dates

Key Milestone

3.5 Process Flow Chart



CHAPTER 4
RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Mud Rheology Test

Table 4 shows the mud properties results after rheology test were applied to Saraline and Jatropha Oil Based Mud.

- Saraline = Saraline Oil Based Mud
- Test 1= Jatropha Oil Based Mud with 100% Jatropha oil
- Test 2 = Jatropha Oil Based Mud with 80% Jatropha oil and 20% Toluene
- Test 3 = Jatropha Oil Based Mud with 70% Jatropha oil and 30% Toluene
- Test 4 = Jatropha Oil Based Mud with 60% Jatropha oil and 40% Toluene
- Test 5 = Jatropha Oil Based Mud with 50% Jatropha oil and 50% Toluene
- Test 6 = Jatropha Oil Based Mud with 40% Jatropha oil and 60% Toluene
- Test 7 = Jatropha Oil Based Mud with 30% Jatropha oil and 70% Toluene

Calculation for plastic viscosity, apparent viscosity, and yield point:

- Plastic viscosity , μ_p = 600 RPM reading – 300 RPM reading
- Apparent viscosity, μ_a = 600RPM reading ÷ 2
- Yield Point = 300 RPM reading – Plastic viscosity

TABLE 4: Mud Rheology Test Result

PROPERTIES	SARALINE	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	TEST 6	TEST 7
Mud Density, lb/gal	12.0	12.0	11.9	11.8	11.6	11.6	11.5	11.4
600 Rpm Dial Reading	54	300 ++	278	242	189	169	146	112
300 Rpm Dial Reading	37	215	191	178	150	135	116	92
200 Rpm Dial Reading	21	166	159	150	130	116	94	76
100 Rpm Dial Reading	16	126	123	128	108	86	69	58
6 Rpm Dial Reading	8	74	74	77	72	63	46	29
3 Rpm Dial Reading	3	62	67	70	66	47	35	20
Plastic Viscosity, cP	17	85	87	64	39	34	30	22
Apparent Viscosity, cP	27	150	139	121	94.5	84.5	73	56
Yield Point, lb/100ft^2	20	130	104	114	111	101	86	70
10’’ Gel Strength	10	300++	88	81	67	49	38	24
10’ Gel Strength	13	300++	86	79	67	49	37	26

Based on Table 4, the value of mud density for Saraline Oil Based Mud and Test 1 is 12 ppg while the mud density for test 2 until test 7 decreases gradually from 11.9 to 11.4. Mud rheology test result also shows the value of plastic viscosity and yield point of Jatropha oil based mud from test 1 until test 7 decreases. The value of plastic viscosity for Test 1, Test 2, Test 3, Test 4, Test 5, Test 6, Test 7 are 85, 87, 64, 39, 34, 30 and 22 respectively while the plastic viscosity for Saraline oil based mud is 17. The value of plastic viscosity and yield point for Saraline oil based mud is lower compared to the Jatropha oil based mud in Test 1 until Test 7. The comparison of plastic viscosity and yield point for each test is shown in the Figure 18 below.

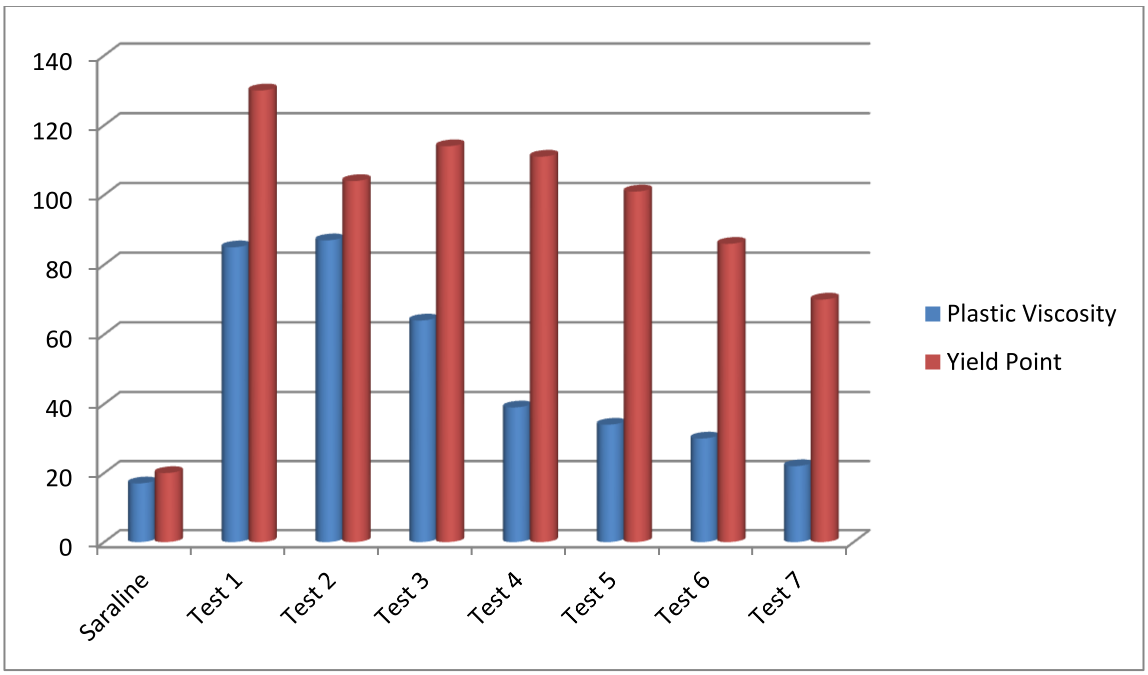


FIGURE 18: Graph of Plastic Viscosity and Yield Point

4.1.2 Multispecimen Wear Tester Experiment

The experiment to study the lubricity of Saraline and Jatropha oil based mud has been conducted using multispeciment wear tester (MWT) equipment. The result of the experiment is tabulated in graph of coefficient of friction. Figure 19 until Figure 25 belows shows the coefficient of friction for each mud.

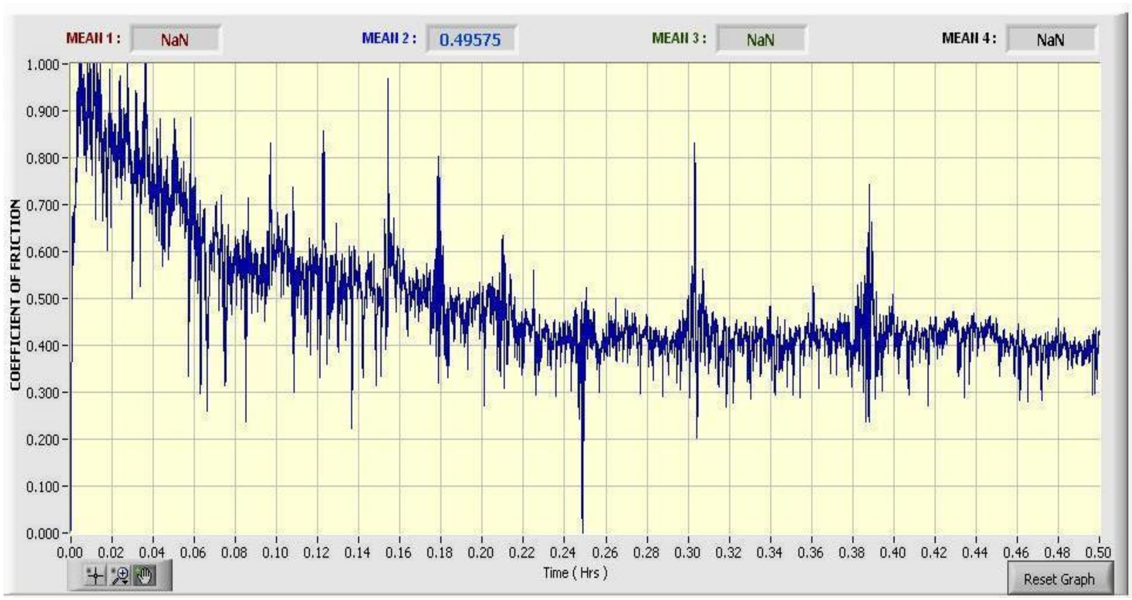


FIGURE 19: Coefficient of Friction Graph for Saraline Oil Based Mud

The Figure 19 above shows the coefficient of friction graph for the formulated Saraline oil based mud. The mean value of coefficient of friction for the mud is 0.49575.

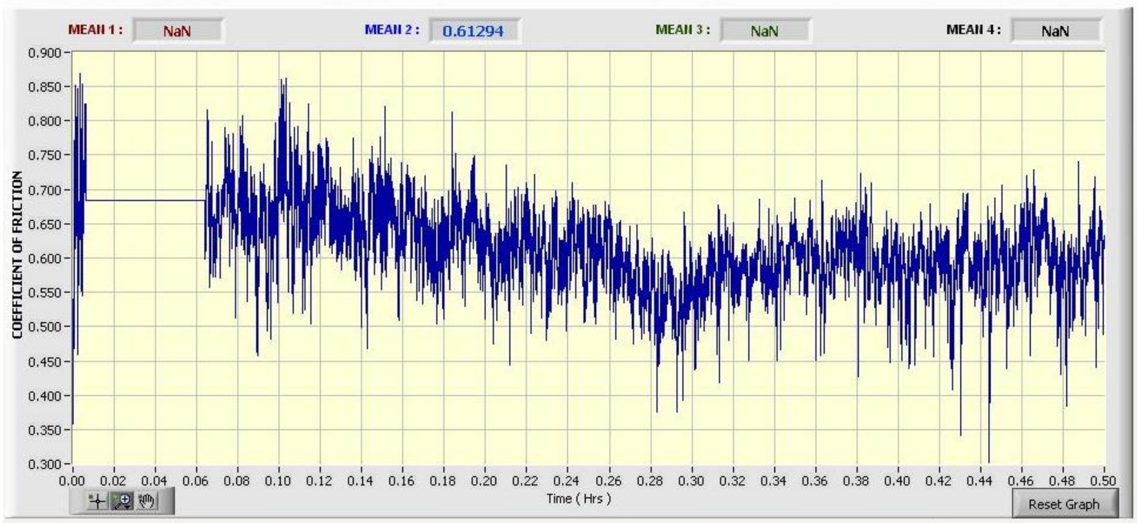


FIGURE 20: Coefficient of Friction Graph for Test 2

The Figure 20 above shows the coefficient of friction graph for the Test 2 mud. Test 2 mud is formulated using 80% Jatropha oil and 20% Toluene. The mean value of coefficient of friction for the mud is 0.61294.

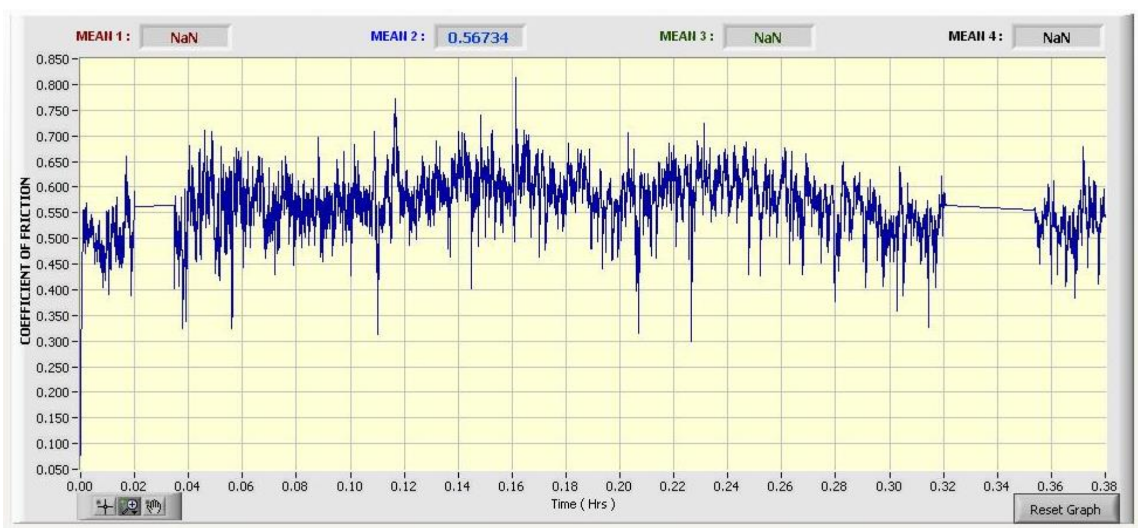


FIGURE 21: Coefficient of Fiction Graph for Test 3

The Figure 21 above shows the coefficient of friction graph for the Test 3 mud. Test 3 mud is formulated using 70% Jatropha oil and 30% Toluene. The mean value of coefficient of friction for the mud is 0.56734.

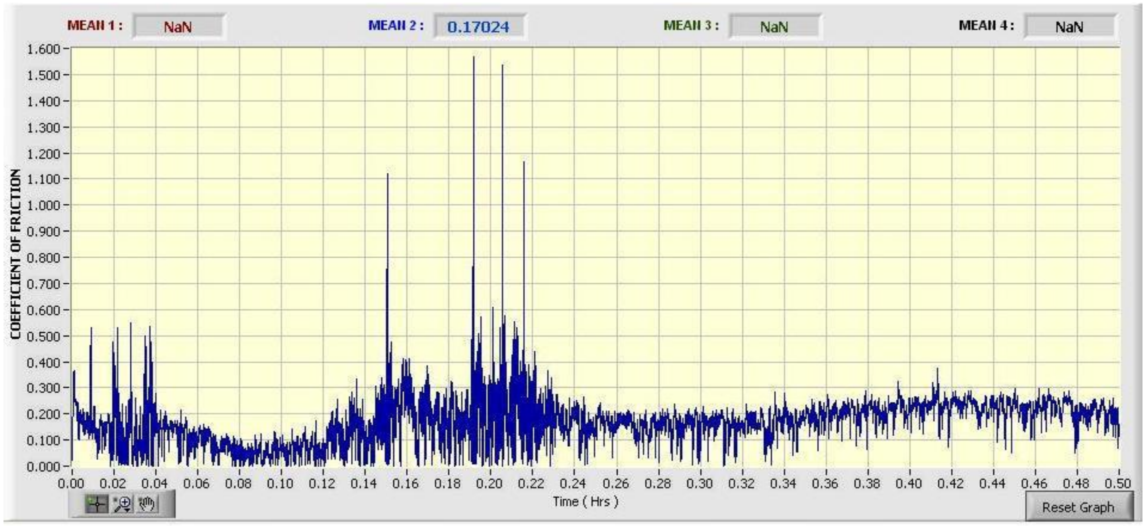


FIGURE 22: Coefficient of Fiction Graph for Test 4

The Figure 22 above shows the coefficient of friction graph for the Test 4 mud. Test 4 mud is formulated using 60% Jatropha oil and 40% Toluene. The mean value of coefficient of friction for the mud is 0.17024.

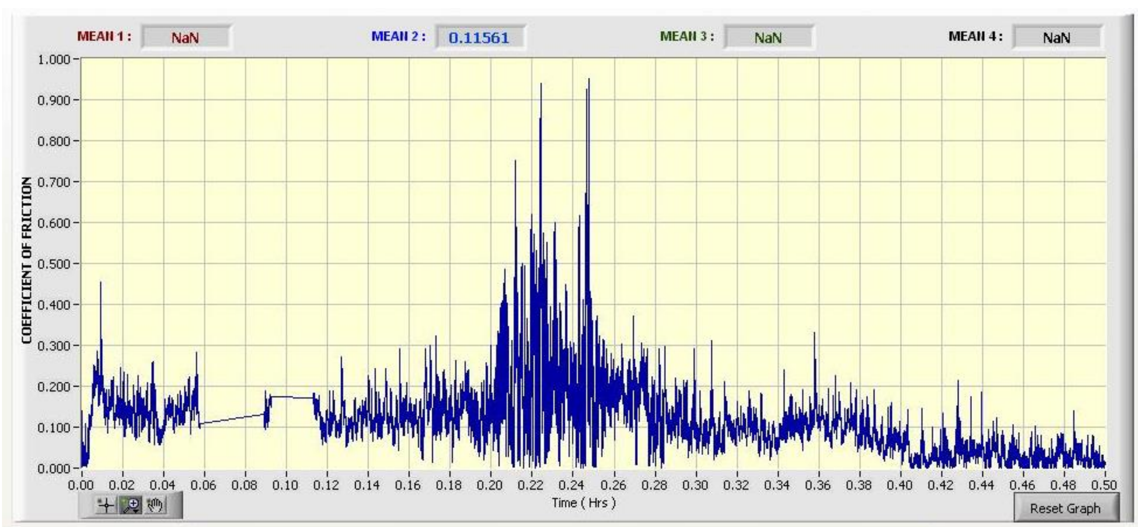


FIGURE 23: Coefficient of Friction Graph for Test 5

The Figure 23 above shows the coefficient of friction graph for the Test 5 mud. Test 5 mud is formulated using 50% Jatropha oil and 50% Toluene. The mean value of coefficient of friction for the mud is 0.11561.

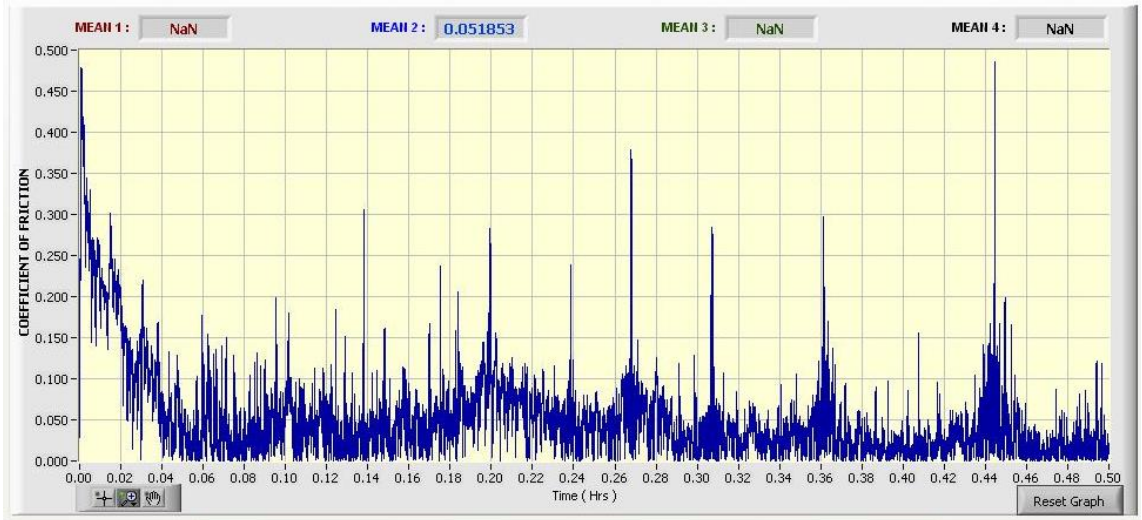


FIGURE 24: Coefficient of Friction Graph for Test 6

The Figure 24 above shows the coefficient of friction graph for the Test 6 mud. Test 6 mud is formulated using 40% Jatrpha oil and 60% Toluene. The mean value of coefficient of friction for the mud is 0.051853.

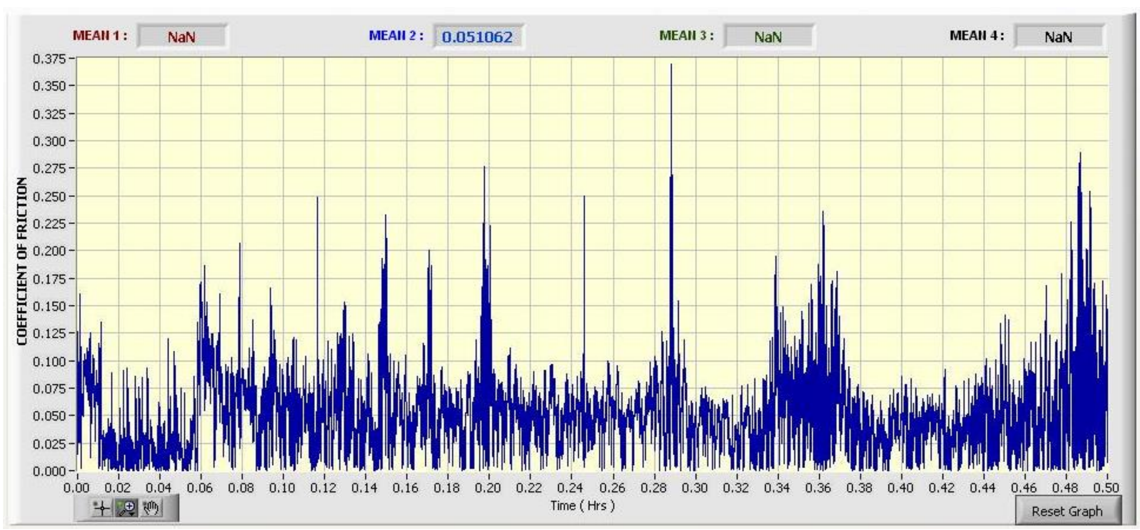


FIGURE 25: Coefficient of Friction Graph for Test 7

The Figure 25 above shows the coefficient of friction graph for the Test 7 mud. Test 7 mud is formulated using 30% Jatrpha oil and 70% Toluene. The mean value of coefficient of friction for the mud is 0.51062.

TABLE 5: Coefficient of Friction for All Tests

Test	Coefficient of Friction, COF
Saraline	0.49575
Test 2	0.61294
Test 3	0.56734
Test 4	0.17024
Test 5	0.11561
Test 6	0.051853
Test 7	0.051062

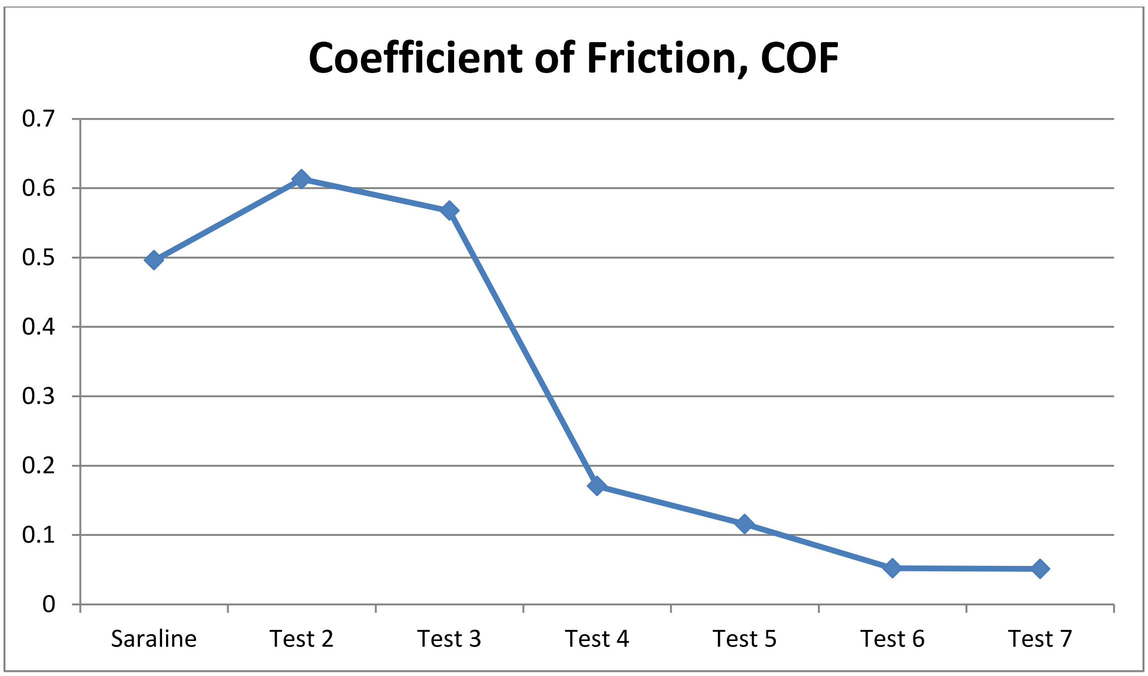


FIGURE 26: Coefficient of Friction Graph for All Tests

Table 5 and Figure 26 above show the value of coefficient of friction for all tests. In the graph on Figure 26, the value of coefficient of friction for Test 7 has the lowest value while Test 2 has the highest value. However, the coefficient of friction for Saraline oil based mud is higher compared to the coefficient of friction for Test 4, Test 5, Test 6 and Test 7.

4.1.3 Wear Analysis

The surface of the granite disk and the difference of the weight for the steel pin after multispecimen wear tester experiment are observed to analyze the wear effect of drilling mud to the drill string. Figure 27 until Figure 33 below shows the surface of the granite disk. The circle in the second column of each figure indicates the wear effect between the pin and the granite disk.

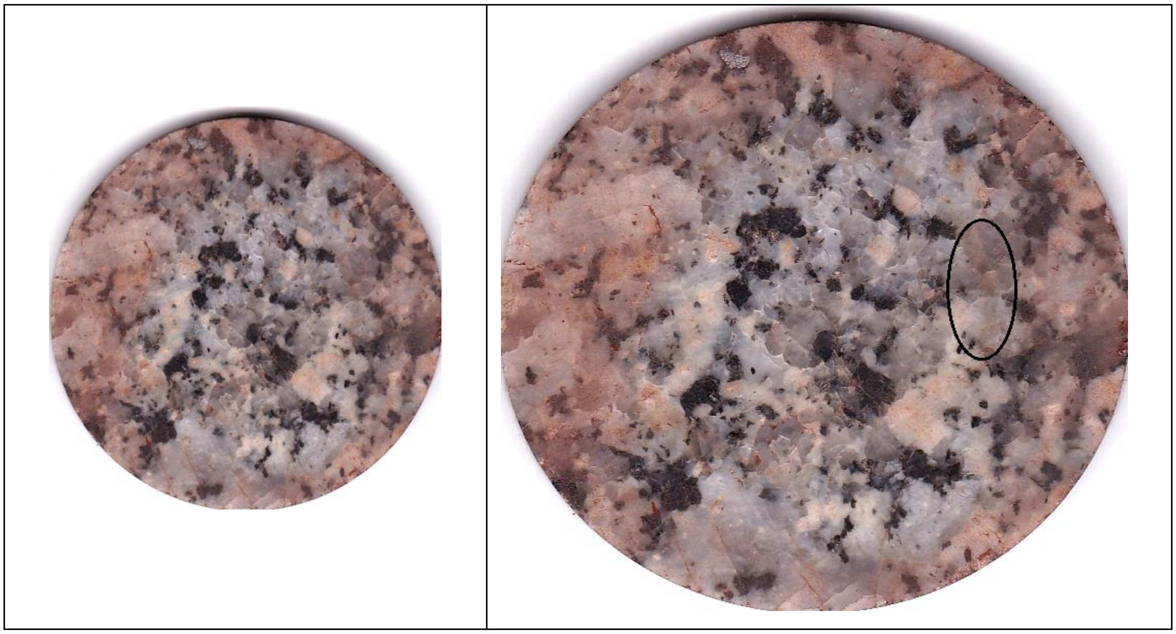


FIGURE 27: Granite Disk Surface After tested with Saraline

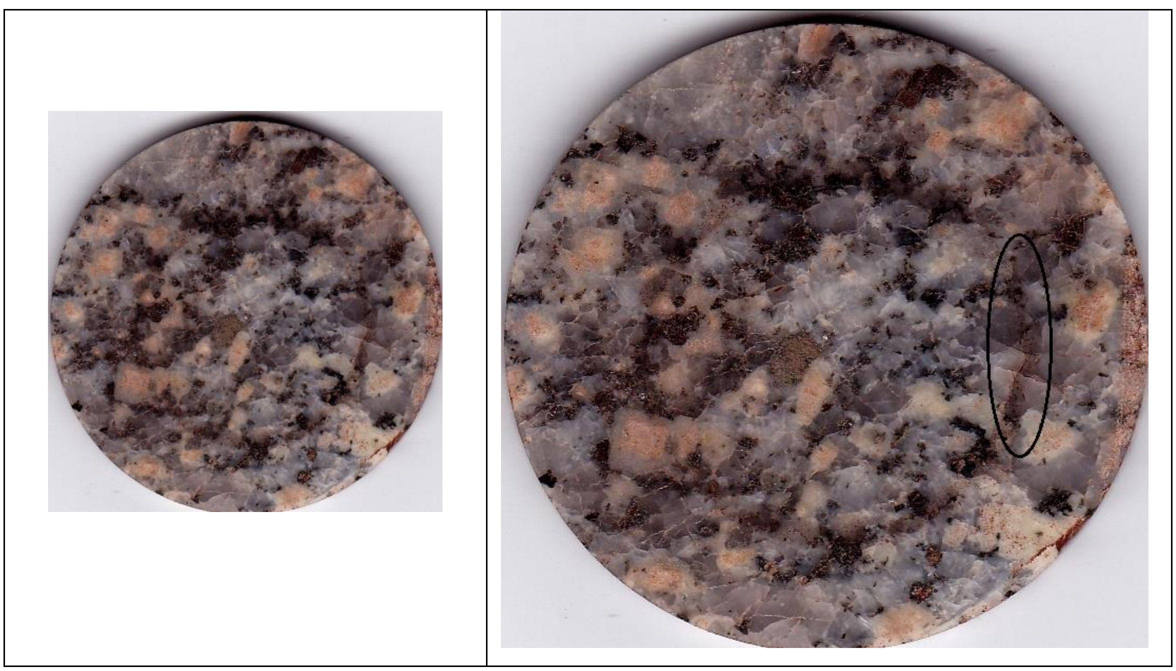


FIGURE28: Granite Disk Surface After tested with Test 2

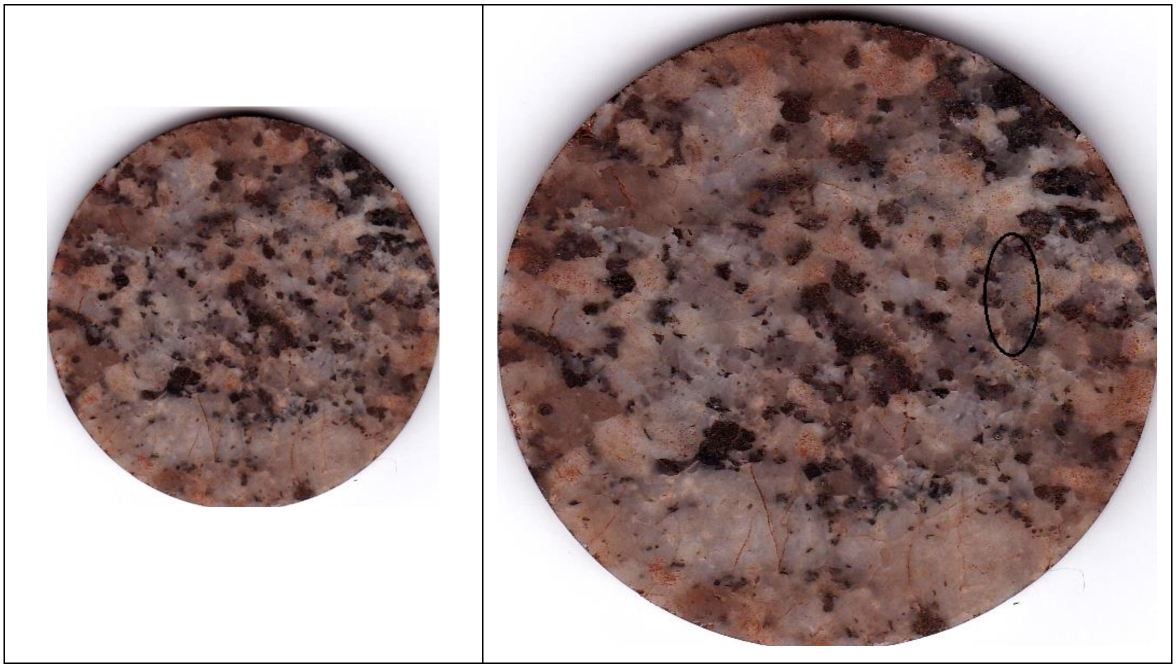


FIGURE 29: Granite Disk Surface After tested with Test 3

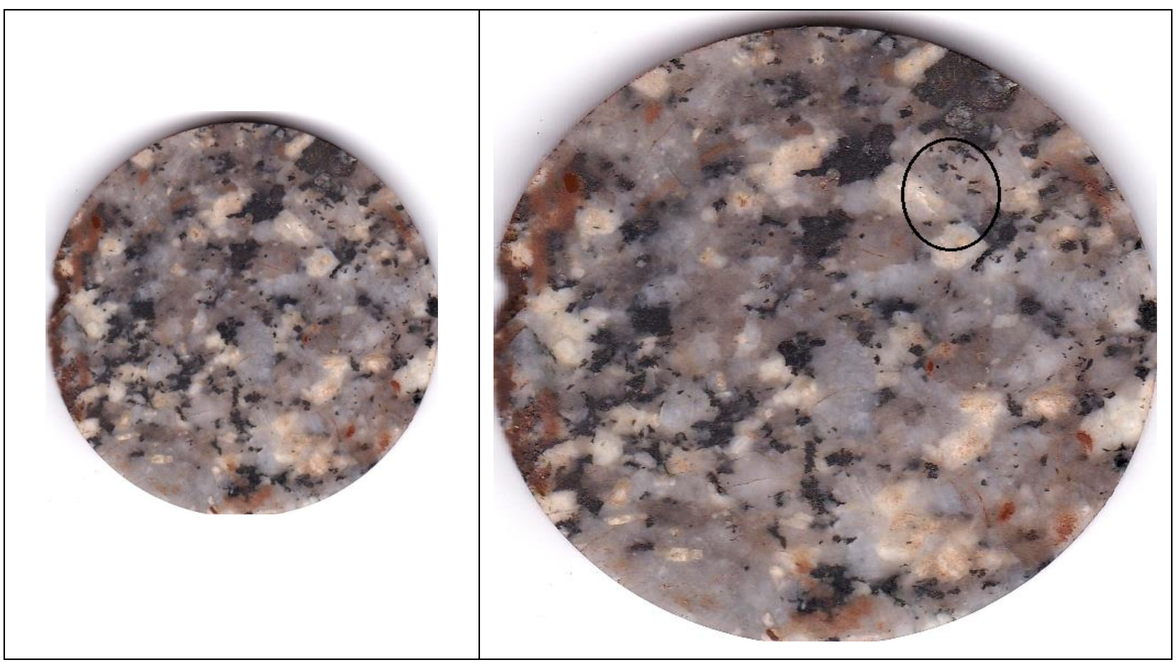


FIGURE 30: Granite Disk Surface After tested with Test 4

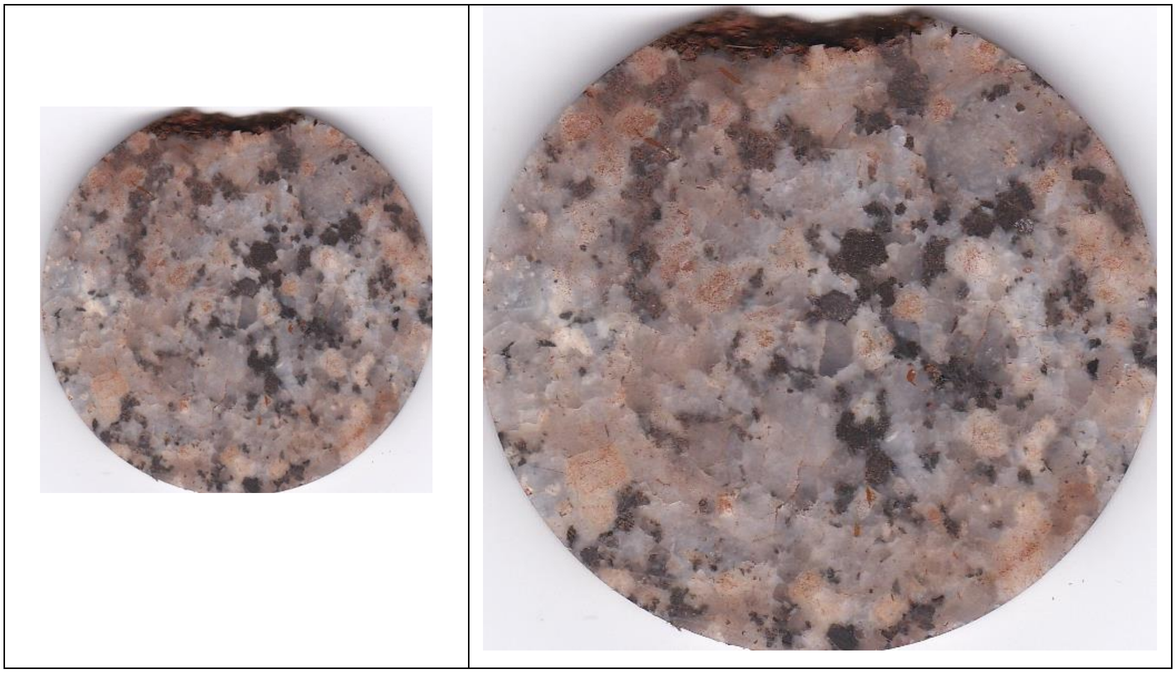


FIGURE 31: Granite Disk Surface After tested with Test 5

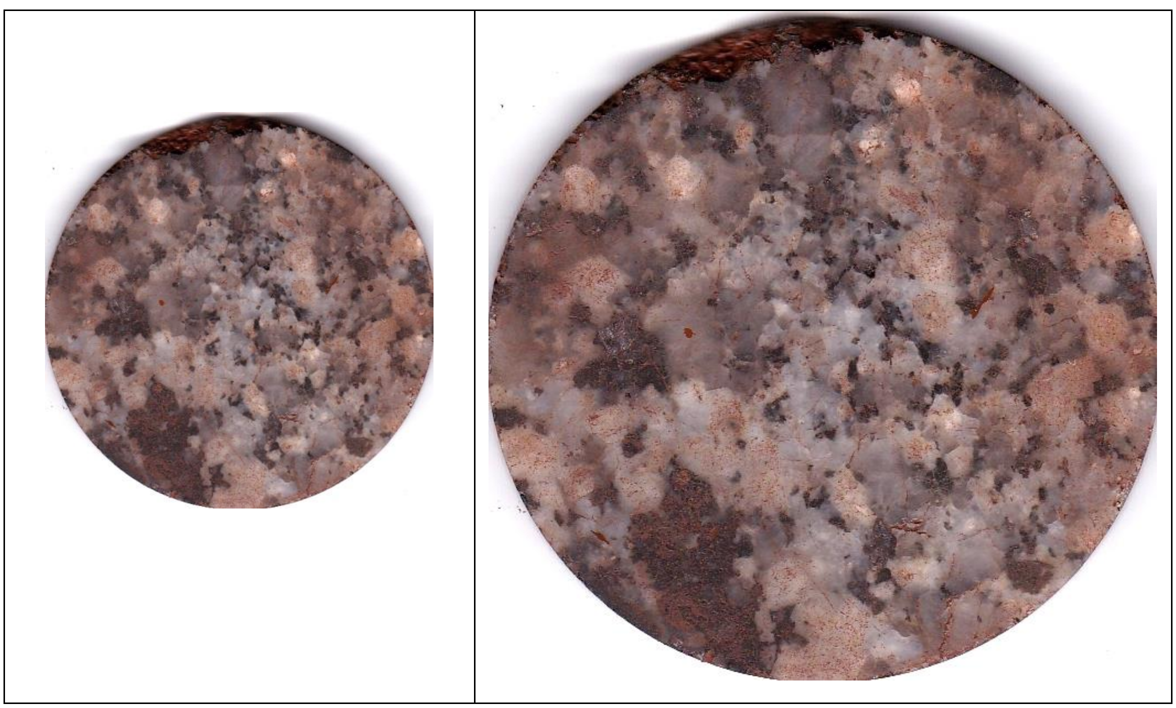


FIGURE 32: Granite Disk Surface After tested with Test 6

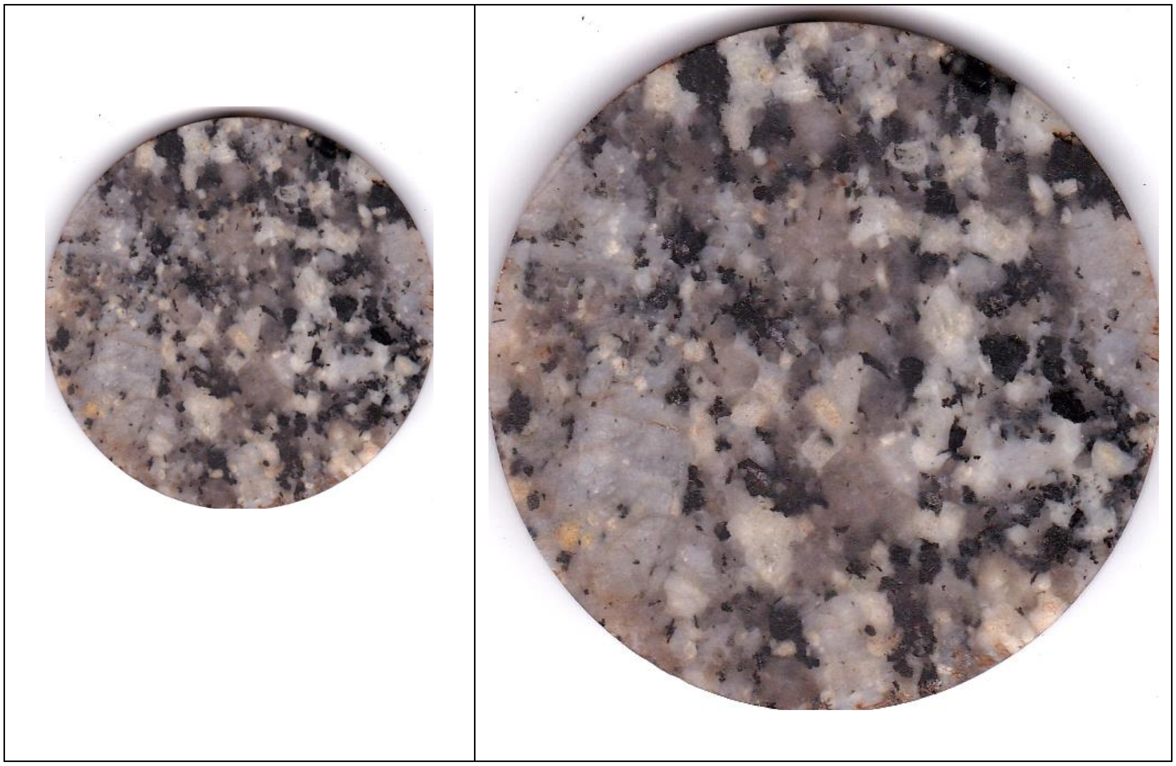


FIGURE 33: Granite Disk Surface After tested with Test 7

Table 6 below shows the weight of the steel pin before and after the multispecimen wear tester experiment and its differences while Table 7 below shows the weight of the granite disk before and after the multispecimen wear tester experiment and its differences

TABLE 6: Weight of Pin Before and After Experiment

Test	Weight of Pin Before Experiment, g	Weight of Pin After Experiment, g	Difference, g
Saraline	3.229	3.228	-0.001
Test 2	3.221	3.220	-0.001
Test 3	3.222	3.221	-0.001
Test 4	3.223	3.222	-0.001
Test 5	3.221	3.220	-0.001
Test 6	3.223	3.222	-0.001
Test 7	3.228	3.227	-0.001

TABLE 7: Weight of Granite Disk Before and After Experiment

Test	Weight of Granite Disk Before Experiment, g	Weight of Granite Disk After Experiment, g	Difference, g
Saraline	`17.677	17.689	0.012
Test 2	16.329	16.338	0.009
Test 3	15.874	15.882	0.008
Test 4	19.361	19.376	0.015
Test 5	17.897	17.907	0.010
Test 6	18.853	18.872	0.019
Test 7	19.072	19.086	0.014

4.2 DISCUSSION

4.2.1 Mud Rheology Test

The Jatropha oil based mud and Saraline based mud is made using the formulation in Table 3 above. The main materials to formulate the drilling mud is Toluene, Confi-Mul P, Confi-Mul S, Confi-Gel, Confi-Trol, lime, fresh water, Calcium Chloride and Drill-Bar.

The Toluene acid or also can be known as methylbenzene is used in this mud formulation because the specific gravity for the crude Jatropha oil is too high. The main function of Toluene acid is to dilute the Jatropha oil so that the specific gravity of blended solution will be reduce and hence can made the oil based mud suitable for use in industry. The resulting solution is in uniform solution without precipitates. In order to know the exact amount/percentage of Toluene that need to be used to dilute crude Jatropha oil, there are six test need to be done with difference value of percentage of Toluene acid in crude Jatropha oil which are 20%, 30%, 40% ,50%, 60% and 70% of Toluene acid.

Confi-Mul P is a formulated blend of emulsifiers for use a s a primary emulsifier formulated by SCOMI Oiltools. Its main function is to produce stable emulsions which are resistant to high temperatures and to contaminations. Meanwhile confi-Mul S is a proprietary surfactant blend for use as a secondary emulsifier and its function is to provide emulsion stability as well as high temperature tolerance and resistance to contamination.

Confi-Gel is another product from SCOMI Oiltools which provide an effective viscosifier and as gelling agent for synthetic and oil-based mud. Besides that, Confi-Trol is also used in JOBM to act as an agent that causes minimal viscosity increase and is effective in controlling HPHT filtration in the invert oil base systems over a wide range of temperatures. Lime is also required in the mud formulation because it is use to activate the emulsion and provide tight fluid loss control. Besides, Calcium chloride, CaCl is also used to activate the lime properties in the drilling mud. Lastly, the Drill-Bar is also a product of SCOMI Oiltools that is used as the primary weight material in drilling fluids.

4.2.1.1 Mud Density

Based on Table 4, Test 1 until Test 7 has a different value of mud density because of the the effect of percentage volume of Toluene acid in the mud. In test 1, the percentage of Toluene in Jatropha solution is 20% and the mud density is 11.9ppg while in test 6, the percentage of Toluene in the Jatropha solution is 70% and the mud density is 11.4ppg. The higher the percentage of Toluene acid in Jatropha oil solution, the lower the mud density.

4.2.1.2 Plastic Viscosity and Yield Point

Based on the Figure 18, the Test 1 has the highest value of plastic viscosity and yield point compared to other test because the mud in test 1 contains 100% Jatropha oil. The Jatropha oil has a very high specific gravity and hence makes the mud become too viscous. Based on the figure 18 also, Test 7 which contains 30% of Jatropha oil and 70% Toluene has the lowest value of plastic viscosity and yield point compared to the Test 1 until Test 6 because the Jatropha oil has been diluted with Toluene. The higher the percentage of Toluene in the Jatropha oil based mud, the lower the specific gravity of the solution and the value of plastic viscosity and yield point become lower. It is concluded that the Jatropha oil based mud in Test 1 until test 6 are not suitable to be used as drilling mud in the industry because it's have a high plastic viscosity and yield point.

When Saraline oil is compared with all the Jatropha oil based mud in the test, Saraline oil has a lower plastic viscosity and yield point and hence shows that it has a better and preferable characteristic to be used as base fluid in drilling mud. Moreover, nowadays, Saraline oil is commercially used as a fluid base in the industry due to its preferable rheological properties.

In conclusion, Saraline oil based mud has a better rheological properties compared to the Jatropha oil based mud although the Jatropha oil has been diluted with Toluene until 70% of its content.

4.2.2 Multispecimen Wear Tester Experiment

The multispecimen wear tester (MWT) equipment was used to study the lubricity of the drilling fluid on granite disk and steel pin. The granite disk represents as a wellbore formation while the steel pin represents the drill string during drilling operation. The experiment is conducted for 30 minutes for each test. The mud in test 1 is does not been tested with multispecimen wear tester because the mud is too viscous and suitable to be used in industry. The results of the experiment are in the form of coefficient of friction graph.

Based on Figure 26, it is shows that the Test 7 that contains 70% Toluene and 30% Jatropha oil has the lowest value of coefficient of friction compared to other

Jatropha oil based mud. This is because, the mud in test 7 is more dilute compared to others and has a lower plastic viscosity and yield point. This shows that the plastic viscosity and yield point plays important roles on the lubricity of the mud.

The Figure 26 also shows that the coefficient of friction for Test 4, Test 5, Test 6 and Test 7 are lower than the value of coefficient of friction for Saraline oil based mud. This shows that the Jatropha oil based mud has a better lubricity compared to Saraline oil based mud although the plastic viscosity and yield point is much higher. This is happen because of the fatty acid contents in the Jatropha oil. According to Hu J. et al (2004), Fatty acid methyl esters and monoglycerides were the main compositions affecting the lubricity properties of biodiesel. The amount of free fatty acid in Jatropha oil is 10.1%.

In conclusion, the Jatropha oil based mud has a better lubricity in drilling operation compared to the Saraline oil based mud. The value of coefficient of friction of Jatropha oil based mud that has been diluted with 70% of Toluene is 0.051062 while the value of coefficient of friction for Saraline oil based mud is 0.49575.

4.2.2 Wear Analysis

Figure 27 until Figure 33 below shows the surface of the granite disk. Figure 27 shows the wear effect on granite disk after being tested with Saraline oil based mud. The wear effects on the disk surface are visible and can be observed with naked eye. This shows the mud has poor lubricity properties. Granite disk in Figure 28, Figure 29 and Figure 30 also have a visible wear effects on its surface. This also shows that the mud a poor lubrication properties. However, in Figure 31, Figure 32 and Figure 33, the wear effects are not visible on the surface of the granite disk and cannot be observed with naked eye. This shows that the mud have a good lubricity.

Table 6 shows the weight of steel pin before and after the multispecimen wear tester experiment. The difference in weight of the pin is same for all tests which is decrease by 0.001 gram. The value is same for all test although the coefficient of friction for each mud are varies from each other because the sensitivity of the electronic balance is too big. The effects of wear on steel pin are too small to be measured by only three decimal places.

Meanwhile, Table 7 shows the weight of granite disk before and after the experiments conducted. The weight of all granite disks were increased after the experiments although being exerted a friction force for 30 minutes because the mud fill the cracks and the pore spaces on the granite disk. So, the weight of the granite disk cannot be used as a parameter to find the wear effects.

In conclusion, there is a wear effects on granite disk and steel pin that can be observed after being tested with Saraline oil based mud meanwhile there is no wear effects visible on granite disks and steel pin after being tested with Jatropha mud oil based in Test 5, Test 6 and Test 7.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Based on the objectives stated by the author above, it can be concluded that the Jatropha oil based mud have a better lubricity compared to the Saraline oil based mud. The value of coefficient of friction of Jatropha oil based mud that has been diluted with 70% of Toluene is 0.051062 while the value of coefficient of friction for Saraline oil based mud is 0.49575. This shows the lubricity of the Jatropha oil based mud is much higher than the Saraline oil based mud. Furthermore, the Jatropha oil based mud also exhibits a low wear effects on the granite disk and steel pin compared to the saraline oil based mud.

However, based on the rheological test result, the Jatropha oil based mud does not acquire much of an ideal base fluid used as the drilling mud in industry without being diluted because it has a very high plastic viscosity and yield point. Moreover, after being diluted with 70% of Toluene, the plastic viscosity and yield point is still higher than the Saraline oil based mud. But it can be treated by changing the mud formulation and dilute the Jatropha oil using another chemicals.

5.2 RECOMMENDATION

For future studies, the author recommends to study the lubricity of Jatropha oil based mud using a different mud formulation and chemicals to dilute the Jatropha oil. By using a different approach to dilute and formulate the Jatropha oil based mud, the suitability of the mud to be used as drilling fluid in industry can be studied.

Besides that, the author would recommend to use a more sensitive electronic balance to measure the weight of the pin steel before and after the experiment so that can get an accurate result on wear effects.

Lastly, the author also wants to suggest to use a granite disk that has no pore and cracks in their surface when conducting the multispecimen wear tester experiment. By doing this, the study of the effects of wear on granite disk can be studied by comparing the granite disk weight before and after conducting the experiment.

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APPENDICES

BIONAS

BIONAS CRUDE JATROPHA OIL SPECIFICATION

Properties	Crude Jatropha Oil (CJO)
Density at 15°C (kg/L)	0.92
Flash Point (°C)	240
Kinematic Viscosity @30°C (cSt)	52
Appearance	Similar to Castor Oil
Solubility	Organic solvents. Insoluble in water.
Odour	Similar to Raw Castor Oil
Color	Golden Yellow
Refractive Index	1.4735
Free Fatty Acids (% as C18:1)	10.1
Acid Value (mg KOH/g)	10.5
Total Saturated (%)	22.3
Total Mono Unsaturated (%)	42-43.1
Total PUFA (%)	34-36
Iodine Value (mg I_2 /g)	97.1—111.6
Peroxide value (mg reac. O_2/g)	3.5
Saponification Value (mg KOH/g)	169.9—197
Calorific Value (MJ/kg)	37.8

Note: Since it is a natural product, the exact physical and chemical data may vary from that mentioned in this specification.