

EXPERIMENTAL INVESTIGATION ON SURFACE TENSION AND DENSITY OF BIODIESELS AS FUNCTIONS OF TEMPERATURE

SKRIPSI

JAGADDHITA PANDYA ATMAJA 0706303092 FADIL WIMALA DARMANTO 0706257426

FAKULTAS TEKNIK PROGRAM STUDI INTERNASIONAL TEKNIK MESIN

DEPOK JULI 2012

LEMBAR PENGESAHAN

Skripsi ini diajukan oleh

Nama : Jagaddhita Pandya Atmaja

NPM : 0706303092

Program Studi : Teknik Mesin

Judul : Experimental Investigation on Surface

Tension and Density of Biodiesels as

Functions of Temperature

Telah berhasil dipertahankan di hadapan Dewan Penguji dan diterima sebagai bagian persyaratan yang diperlukan untuk memperoleh gelar Sarjana Teknik pada Program Studi Teknik Mesin, Fakultas Teknik, Universitas Indonesia.

DEWAN PENGUJI

Pembimbing : Associate Professor. Richard Brown

Penguji 1 : SANGANG SUBLATORO (...

Penguji 3 : Vulianto S Nugroho (VVI)

Ditetapkan di : Depok

Tanggal : 27 Juli 2012

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Nama: Jagaddhita Pandya Atmaja

NPM: 0706303092

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Acknowledgements

First of all, we would like to thank the project supervisor Associate Professor Richard Brown for all the support and assistance that made the experiments on surface tension and density of biodiesels possible. Without his continuous support, it would not have been possible for us to perform the experiment within the given time frame. We also want to extend our thanks to Muhammad Jahirul Islam as the project coordinator, for his continuous guidance and support during the semester.

Secondly, we wish to acknowledge and thank Mr. Eric Martinez who accommodated the laboratory and provided technical assistance during the experiments of surface tension and density, ensuring all the tools and equipment were available for the measurements. Finally, we would like to thank the whole Biofuel Engine Research Facility team, specifically Kah Ming Jon Chan for the kind assistance in sending out the minutes of meeting and all other important materials related to the project via e-mail.

Abstract

In order to respond the global issues regarding climate change and global warming in this new era of globalization, governments and environmentalists set the targets to provide an alternative, sustainable and renewable energy to decrease the pollution emerging from non-sustainable sources such as a fossil fuels or petrodiesel. The increase in the use of biodiesel fuels is expected to be a better solution to help address the environmental problems impacting on society.

Biodiesels are an alternative, environmentally friendly energy resources generated from the transesterification process of animal fats, vegetable oils and other organic resources. The transesterification process of biodiesels can be carried on by using an alkaline as the catalyst to separates the triacylglycerol into an alkyl ester and a glycerol compound. Through this separation, a friendly chemical component similar with a fossil fuel can be produced. Nevertheless, further characteristics of biodiesels need to be observed in order to maximize the performance of biodiesels on the diesel engine.

This report will focus on surface tension and density experimental investigations of four biodiesel fuels and nine fractionated methyl ester based on temperature dependency. The results are evidence of the relationship between surface tension and density. Also, the temperature change data characterizes the impact of fatty acid chain length upon density and surface tension.

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Aim and Objectives

This project examines the surface tension and density of four biodiesel fuels and nine fractionated methyl ester as a function of temperature, based on the experimental performance result. This project also aims to find the relationship between temperature dependence and characterization of the effect of chain length upon surface tension and density. The experiment has been conducted in the QUT laboratory, E block room E 406, using a KSV Sigma 702 Tensiometer in order to collect the data from all the samples. All result data gained from the experiment are analysed and compared with the results from current literature.



1. Introduction

Growing concern for the environment has led many to research for the most sustainable internal combustion engine that can conveniently be used for everyday applications. Currently, we rely heavily on the two common types of internal combustion engine: gasoline/ petrol engines and diesel engines. These two engines differ in their features and the amount of emissions. Carbon dioxide emissions from petrodiesel fuel diesel engines are lower than for gasoline engines of comparable age, condition, and capability due to the inherent fuel efficiency of the diesel engine. In that regard, the diesel can be considered superior to the gasoline engine. The current diesel engines are also much cleaner than earlier versions due to changes in their design that result in more complete combustion of the fuel making them the most efficient prime mover available. The high power, high torque, and most importantly the high fuel efficiency of the diesel engines that reduces the amount of fuel required, are the reasons why they are universally used in society. However, due to heavy reliance on diesel technology, the global contribution of carbon dioxide to the atmosphere from diesels is still significant. The pollution emitted by diesel engines with petrodiesel fuel contributes to a number of environmental and human health concerns.

In addition to the environmental concerns with traditional petroleum based diesel (petrodiesel), petrodiesel is not renewable. According to statistics released by *British Petroleum*, global oil supplies will be exhausted in the next 40 years [1] or much sooner as the models used for the predictions cannot accurately account for the increasing use of oil in developing countries [2] As the oil supply decreases, it will reach a point where the energy required, to find and extract one barrel worth of oil will be substantially greater than the energy contained in one barrel of oil itself [2].

These issues have revived interests in the use of biodiesel as the next primary fuel for diesel engines due to its lower emissions and renewable nature as opposed to conventional diesel, which is a fossil fuel that can be depleted. However, because the fuel properties of biodiesel and petrodiesel fuel are different, differences in engine performance also exist. The higher viscosity of biodiesels shows that the cold flow properties of biodiesel are poor and may cause problems in engine starter and limits the use of biodiesel in cold climates. For these reasons, more investigation into the fuel properties of biodiesels is required.

2. Biodiesel properties

2.1 Surface Tension

Surface tension is defined as a force existing in the surface of a body, prone to minimizing the area of the surface due to the effect of intermolecular attraction force between the liquid molecules at the liquid outside boundaries. Surface tension is an important parameter of biodiesels that relates to fuel combustion and atomization quality on the combustion process on the diesel engine. Atomization properties on the surface tension can affect the injection process on the combustion chamber as well as the ignition process. It is also can affect the emissions of the diesel engine. Surface tension can be determined by using the equation:

$$\gamma = \frac{F}{L}$$

Where:

 γ =Surface tension (N/m)

F = Force exerted parallel to the liquid (N)

L = Length of the line over where force acts (m)

2.2 Density

Density is defined as mass per unit volume. Density is the most important properties of biodiesel that can affect the performance of a diesel engine. It is important for diesel engine performance because fuel injection operates on a volume metering system. This means, the changes in the fuel density influence engine output power due to a different mass of fuel injected [3]. Also, the density of the liquid product is required for the estimation of the cetane index. A cetane number means that the diesel will ignite readily and therefore perform better in a diesel engine. On the other hand, biodiesel with higher density leads to poorer atomization quality of the fuel spray and less accurate operation of the fuel injectors. Density can be determined by using the equation:

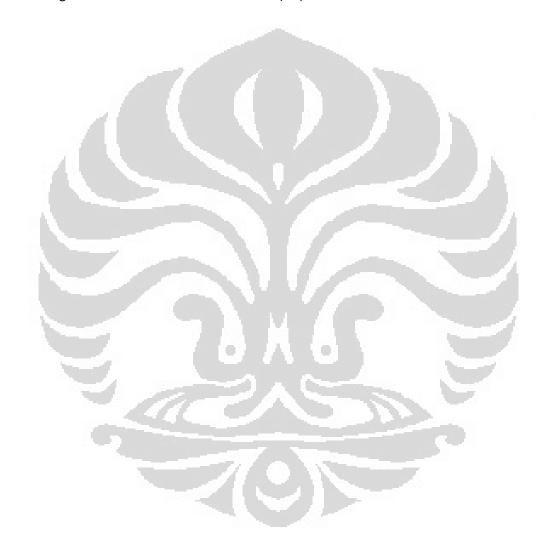
$$\rho = \frac{m}{V}$$

Where:

 ρ =Density (kg/m³)

m = Force exerted parallel to the liquid (kg)

V = Length of the line over where force acts (m³)



2.3 Fuel Sample Fatty Acid Profile

Table 2-1: Fatty acid composition of all 13 biodiesel samples. Note that on the table, pure 810, pure 1214 and pure 1875A are 100%. 810-1214, 810-1875A, 1214-1875A are 50-50 mixes.

Main 1875A, Main 810 and Main 1214 are 2/3-1/6-1/6 mix where the 2/3 component is as indicated

	Fatty acid content												
	C6	C8	C10	C12	C14	C16	C16:1	C18	C18:1	C18:2	C18:3	C20	C20:1
Pure 810	0.043	0.541	0.406	0.01	0	0	0	0	0	0	0	0	0
Pure 1214	0	0.003	0.006	0.7	0.236	0.05	0	0.005	0	0	0	0	0
Pure 1875A	0	0	0	0.002	0.01	0.21	0	0.77	0	0	0	0.008	0
810-1214	0.021	0.272	0.206	0.355	0.118	0.025	0	0.003	0	0	0	0	0
810-1875A	0.021	0.271	0.203	0.006	0.005	0.105	0	0.385	0	0	0	0.004	0
1214-1875A	0	0.001	0.003	0.351	0.123	0.13	0	0.388	0	0	0	0.004	0
Main 1875A	0.007	0.09	0.069	0.12	0.046	0.148	0	0.515	0	0	0	0.005	0
Main 810	0.029	0.361	0.272	0.124	0.041	0.043	0	0.129	0	0	0	0.001	0
Main 1214	0.007	0.092	0.072	0.469	0.159	0.068	0	0.132	0	0	0	0.001	0
Canola	0	0	0	0	0	0.037	0	0.017	0.594	0.235	0.102	0.015	0
Cottonseed	0	0	0	0	0.008	0.2445	0.007	0.0235	0.171	0.542	0.0035	0.0005	0
Tallow	0	0	0	0	0.02	0.305	0.03	0.215	0.39	0.03	0.01	0	0
Cooking oil	0	0	0	0	0	0.096	0.012	0.035	0.58	0.179	0.063	0.008	0.027

The fatty acid compositions of the pure esters were obtained from the supplier while for the ester mixtures, the presented values were calculated according to their mixing proportions. It should be noted that all the fatty acid compositions obtained from the ester supplier and pieces of literature consist of a range of values and were thus averaged to yield a single value as shown in table 2-1.

3. Experimental Apparatuses and Methodology

A KSV Sigma 702 Tensiometer was used to measure the surface tension and density of biodiesel samples in order to observe the change of surface tension and density in relation to the changes of temperature. A KSV Sigma 702 Tensiometer is a stand-alone tensiometer for measuring surface and interfacial tension in situations requiring high sensitivity and simple operation. It was equipped with a large LCD display, touchpad keyboard and can be connected to an external PC in order to store data from the measurement. It can also be connected with different types of probe such as a glass density probe, Du Nouy ring and Wilhelmy plate depending on the type of measurement conducted [8]. During the experiments, the tensiometer was not equipped with the water bath to control the temperature due to an error on the water bath connection. Therefore, an oven was used as a heating apparatus so that the samples reached a temperature above room temperature. A thermocouple was used as a tool to measure the temperature dependence of the samples.



Figure 3-1: KSV Sigma 702 Tensiometer

3.1 Density experiment

The 13 biodiesel samples were measured using the Sigma 702 tensiometer and its density kit. A special glass density probe with known volume and mass was attached to the balance hook and immersed into the biodiesel sample. The force needed to hold the probe at a constant depth in the liquid was then recorded. Once the mass, volume, and supporting weight of the glass density probe were known, the density of the biodiesel sample was calculated. In this case, the software automatically calculates all the parameters needed and obtains the density of the biodiesel samples. For density measurement, the machine works by using a buoyancy method; the application of Archimedes principle. This static technique can cover small density ranges with a high resolution and precision. Based on averaged water density obtained prior to each biodiesel measurement session, an approximate error of 0.106 % was obtained.



Figure 3-2: Glass probe

3.1.1 Preparation

Before starting density measurements for each biodiesel sample, some preparation was required. The glasses for containing the samples during the measurement had to be cleaned thoroughly using ultra pure water, acetone, or chloroform as the substitution for acetone. Once they were rinsed, they had to be air-dried before they could be filled with the samples. The KSV sigma 702 tensiometer had to be calibrated each time it was used. The calibration was done by placing a calibration weight on to the Sigma's balance hook until the machine's screen displayed the correct weight value. The oven for heating the samples was preheated for at least 20 minutes or until the oven reached a steady temperature of 90°Celsius before putting any samples into it. Meanwhile, if the sample vessels appeared to have dried and had no scent of acetone or chloroform, they could finally be filled with the biodiesel samples.

Additional set up was needed for mixture samples, because the samples provided only consisted of; pure 810, pure 1214, pure 1875A, Canola, cottonseed, tallow, and cooking oil. To obtain the remaining samples (810 - 1214, 810 - 1875A, 1214 - 1875A, main 1875A, main 810, and main 1214) mixing was required. These remaining samples were produced by mixing, on mass basis. Proportion varied from, ½:½ or 40.2 g : 40.2 g for two samples and 4/6 : 1/6 : 1/6 or 53.6 g : 13.4 g : 13.4 g for 3 samples mixture such as main 1875A, with 1875A having the large proportion. The mass was measured using the laboratory's weighing balance.

3.1.2 Measurement

The lab contained only one Sigma tensiometer. Therefore, the temperature dependent density measurement for each biodiesel sample could only be done alternately. The measurement for each sample had to be done at several temperatures, ideally every 5° Celsius within the range of room temperature and at a temperature around 70° Celsius. When starting the measurement, the sample was placed onto the machine and the temperature of the biodiesel was recorded using a thermocouple. The measurement always started at the room temperature condition and when the oven was ready, the sample could be placed inside in order to reach a desirable temperature targeting around 70° Celsius. The sample vessel filled with biodiesel was first placed on the machine (sigma tensiometer) and then, a glass density probe was placed on the balance hook and the machine performed the measurement. The measurement for each sample went on until the temperature was approximately 25°Celsius, or 5° Celsius higher than the initial measurement at room temperature condition. Because biodiesel has the tendency to oxidize with air, especially at high temperatures [4], by the end of each measurement, the sample had to be disposed of rather than storing it back to the bottle.

3.2 Surface Tension Experiment

Surface tension measurements were performed at atmospheric pressure and in temperature ranges from 291 – 350 K. For surface tension measurements, the KSV Sigma 702 Tensiometer was connected with a Du Nouy ring. This method can be called the Du Nouy ring method or maximum pull method. Further explanation about the methodology of Du Nouy ring method will be discussed in the methodology section.



Figure 3-3: Du Nouy ring

3.2.1 Methodology

The basic theory of Du Nuoy ring method is to measure the force continuously when the ring has contact with the surface of the liquid, until the surface is lowered. In consequence, the $f_{\rm max}$ or maximum force of the liquid can be recorded. This is commonly recorded before the ring detaches from the surface as can be seen from the figure below.

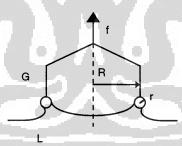


Figure 3-4: Du Nouy ring method

It can also be determined by using this formula:

$$\gamma = \left(\frac{f_{\text{max}}}{4\pi R}\right) \left[F\left(\frac{R^3}{V}, \frac{R}{r}\right)\right]$$

Where:

 γ =Surface tension (N/m)

F = Correction factor

 f_{max} = Maximum force (N)

R = Radius of ring (m)

r = Radius of wire (m)

 $V = f_{\text{max}}/\rho_{\text{L}}$

From the formula above, there are a lot of parameters that need to be observed to obtain the surface tension of the liquid using Du Nouy ring method without connecting it to any other measurement. Therefore, in this experiment the Du Nouy ring was attached with the KSV Sigma 702 Tensiometer so that all the parameters could be observed automatically using the software that has been programmed on KSV Sigma 702 Tensiometer.

The experiments were conducted according to DIN 53419 for the Du Nouy ring and DIN 53993 for interfacial tension. In this method, the surface of the liquid or samples will contact with the Du Nouy ring and then the maximum weight of the liquid lifted by the Du Nouy ring that is pulled out of a liquid surface will be measured. The force (F) required to lift the ring is impacted by the surface tension (s). This expressed through equations = kF. The factor (k) is taken from the capillary pressure across the curved surface of the lifted liquid. The geometrical dimensions of the ring and the contact angle between the ring surface and the liquid effect the (k) factor. To ensure that measurements are accurate the ring should be completely wet by the liquid. In other words, the contact angle should equal zero. The maximum force is determined by repeatedly rising and lowering the ring close to the rupture of liquid lamella hanging from the ring. Just before the rupture, the lamella force applied on the ring decreases dramatically. The balance detects this force change and lowers the ring immediately to the lamella rupture [8]. Based on averaged surface tension of water obtained at the beginning of each biodiesel measurement session, an approximate error of 7.3 % was obtained.

3.2.2 Preparation

Before starting the experiment, all personal protective equipment such as laboratory jackets, safety glasses, and gloves were prepared. The tensiometer was then calibrated using a calibration ring to level the balance correctly. While waiting for the equipment to be calibrated, the oven was set to a temperature of 90°Celsius to get the higher temperature for the samples during the experiments. This allows the samples to cool down during their movement from the oven to tensiometer. The other reason is because the maximum temperature for samples that can allow to measure on the equipment is 80°Celsius. All cups were prepared and cleaned using ultra pure water and acetone or chloroform. For

the surface tension experiment, a butane flame was used to clean the Du Nouy ring after it was cleaned with the acetone. The cup and Du Nouy ring had to be dried before beginning the measurement. Finally, the cups were filled with the samples and put inside the oven until they reached the desired temperature.

3.2.3 Measurement

Firstly, the tensiometer was unlocked. The cup was brought from the oven and placed in the tensiometer in order to measure and record the temperature of the samples using a thermocouple. A Du Nouy ring was connected with the tensiometer right above the surface of the samples before running the equipment to measure the surface tension. Measurement of surface tension started after the "OK" button was pressed. The tensiometer automatically performed the measurements three times on each process and sent all result data to an external PC to be recorded. The process of how the Du Nouy ring measured the surface tension of all the samples can be seen in figure 3-5. The surface tension measurement always started from room temperature and continues until temperature around 70°Celsius by arranging 5°Celsius different ranges in every measurement.

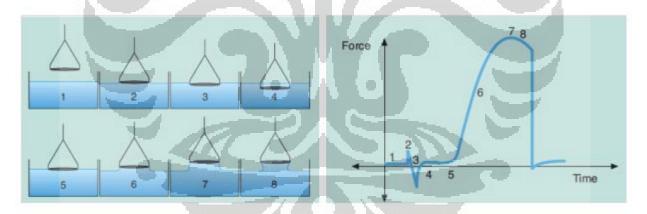


Figure 3-5: Du Nouy ring measurement process

4. Result and Data Analysis

4.1 Density

The experimental density data for four biodiesels, three pure methyl esters, and six mixed methyl esters are reported in table B-1. The experimental data shows that the biodiesel density decreases with an increasing temperature. As was described previously, density is defined as mass per unit volume. Heating a sample of biodiesel causes the volume of the sample to increase while the mass stays the same. Since heat does not have mass, it does not affect the mass of the biodiesel. This increase in volume causes the density to decrease. Conversely, decreasing the temperature of a sample of biodiesel causes the volume of it to decrease while the mass stays the same. This decrease in volume causes the density to increase.

The density of biodiesel usually varies between 0.86 and 0.90g/cm³ at temperature of 20° Celsius

[5]. The data obtained from experimental measurement is consistent with the statement. At both 20° and 70° Celsius, pure 1214 has the lowest density among other biodiesels and the densities of the others are close to each other, as presented in figure 4-1. The highest densities can be seen in cotton seed and canola, with canola having the larger density than cotton seed at high temperatures and cotton seed having a larger density than canola at the lowest temperatures.

Most of the data for mixed samples are within the expectation. Figure B-1 an B-2 show that the density values of the mixed samples (50:50) are in between the values of their pure samples. For main samples (4/6:1/6:1/6)) as shown in figures 8-4, 8-5, and 8-6, their values tend to be closer to the samples that made up the largest proportion in the mixtures. An exception can be seen in figure B-2, as the mixed density values are at the same level as pure 810, which could be resulted from higher concentration of pure 810 in the mixture.

Figure 4-1 shows that the 4 FAME samples from vegetable oils have higher densities than the fractionated methyl esters and petrodiesel.

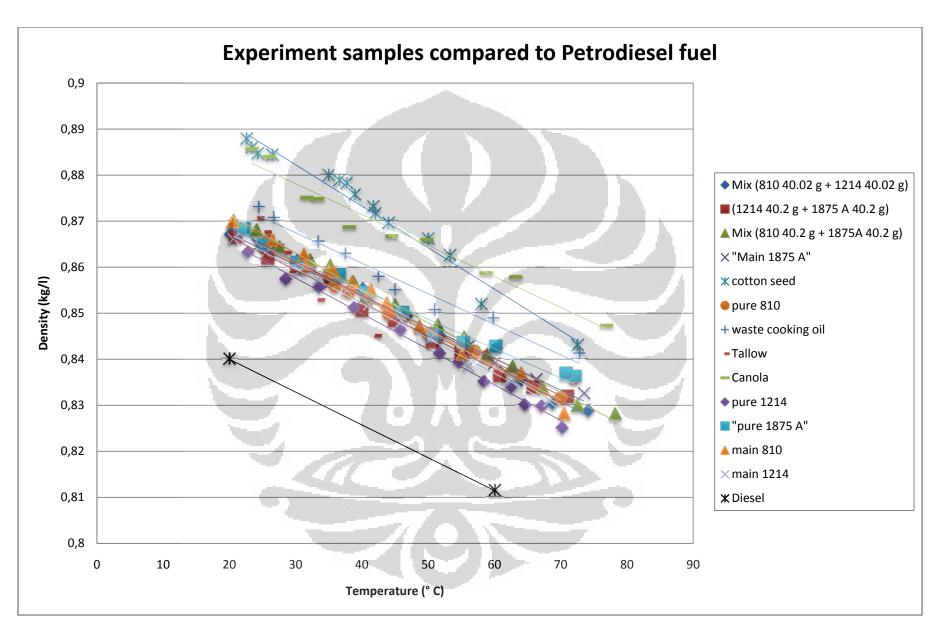


Figure 4-1: Relationship between density and temperature of all 13 biodiesel samples.

4.2 Surface tension

The results of the surface tension experiments were comparable to those from current literature. Tables shown on the appendix C, manifests the averaged results generated from the surface tension measurements of four biodiesels and nine fractionated methyl ester. From the tables on the appendix C it can be seen that all four biodiesels have a greater value of surface tension rather than the nine fractionated methyl ester. Canola shows the higher value of surface tension among the other twelve samples in the high temperature and low temperature range. The chain length factor and degree of saturation plays an important role regarding this result. As it can be seen from fatty acid content on table 2-1, section 2.3. Canola has a chain length of 18 carbon atoms with a single bond and 80-90% of degree saturation. The experiments also revealed that the chain length factor has a significant effect on a surface tension value. This is illustrated in the Methyl Octanoate and Decanoate (810) samples on figure 4-2. The surface tension value of the Methyl Octanoate and Decanoate (810) are lower than the other twelve for high and low temperatures because its chain length only consists of 8 carbon atoms.

Figure 4-2 represents the relationship between surface tension and temperature. It can be seen, that at the lower temperature, all the samples reach the higher number of surface tension. However, when temperatures start to increase, the number of surface tension starts to decline. From analysing figure 4-2an error on the all mixtures samples becomes evident. For the example, the result of the Mixture of Methyl Octanoate and Decanoate (810) with Methyl Stearate (1875A) (50:50 mixture based on weight) show that the value of surface tension is likely to lead to one sample instead of being in the middle of both methyl ester. Mistakes made during heating and mixture processing, can be assumed as the reason or the error.

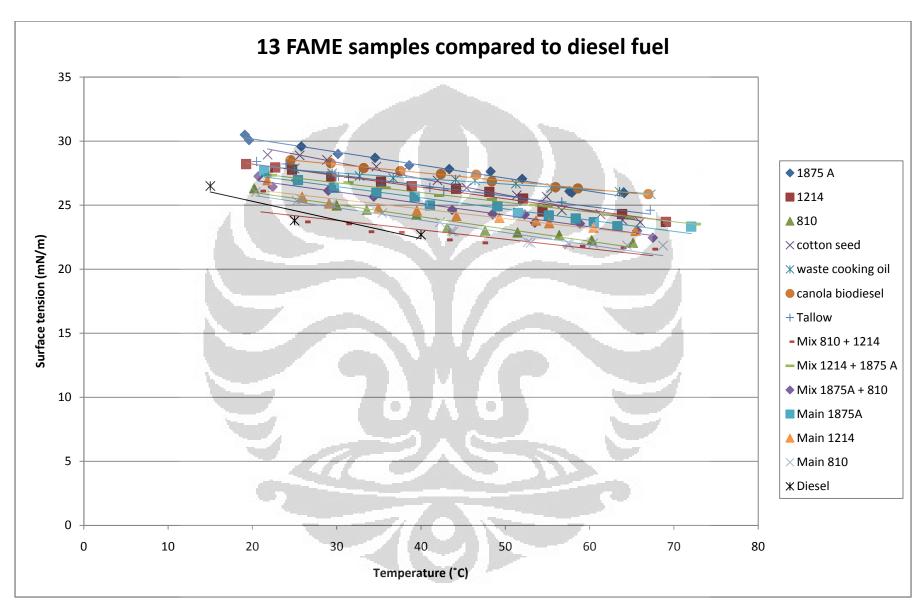


Figure 4-2: Relationship between surface tension and temperature of all 13 biodiesel samples.

5. Discussion

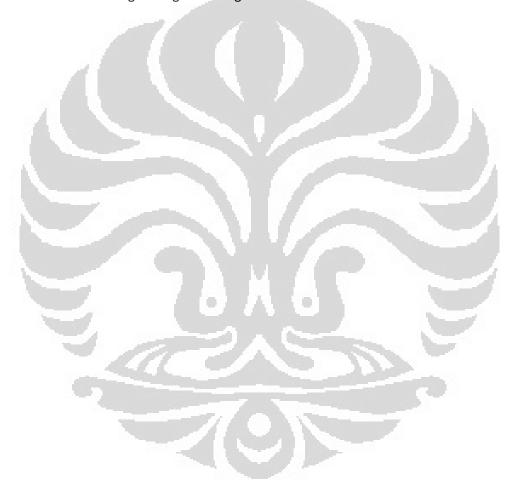
The experimental results of surface tension and density measurement provide a satisfactory result in relation to the change of the temperature. The temperature transition of all the samples affects the value of surface tension and density number. As the expectation, when the temperature of samples increases due to a heating process, surface tension and density shows a decreasing value. Moreover, when the temperature of samples declines, the value of density and surface tension becomes higher.

It is suspected that some errors related to the results for both density and surface tension are due to heating and mixture processing. For example, the Mixture of Methyl Octanoate and Decanoate (810) with Methyl Stearate (1875A) (50:50 mixture based on weight) shows that the value of density and surface tension are likely to lead to one sample instead of being in the middle of both methyl ester, it can be seen on figure 4-1 and Figure 4-2.

Based on both experiment results, for surface tension and density; all four biodiesels have a large number density and surface tension. The other than nine fractionated methyl ester showed a small value when tested at the same temperature. This difference is due to the fatty acid content and degree of saturation of the four biodiesels being higher than the nine fractionated methyl ester. However, in comparison with petrodiesel fuel, both biodiesels and fractionated methyl ester have a larger value of density and surface tension than other than petrodiesel fuel. The significant differences between the fractionated methyl ester and biodiesels at all temperatures that have been tested are explained in the result and data analysis section. In this experiment, cetane number of petrodiesel was the important component that effecting the results.

The major difference between petrodiesel and biodiesels in terms of density, can be compared at a high temperature, low temperature and operational temperature (40 °C). At the high temperature of 60 °Celsius, the average values of density of biodiesels are approximately 0.86 kg/l while for petrodiesel is in the region of 0.81 kg/l. In the mean time, at the lower temperature of 20 °C, biodiesels have average value of density equal to 0.87 kg/l while for petrodiesel is 0.84 kg/l. At 40 °C, density number of biodiesels is around 0.86 kg/l and for petrodiesels is about 0.83 kg/l.

For surface tension, a temperature of 25 °Celsius can be taken as an example to compare the different value of surface tension between petrodiesel and biodiesels. At a temperature of 25 °Celsius biodiesels have a value of surface tension equal to 29.68 mN/m and for petrodiesel equal to 20 mN/m. Based on the discussion about the comparison of density and surface tension number of biodiesels samples with petrodiesel, the used of biodiesels samples tested on the experiment can be used on compression ignition engines. However, biodiesel samples need to be blended with petrodiesel in order to prevent failure of engine parts reacting to the properties of biodiesels. The modifications of engine parts also needs to be conducted to mitigate engine damage.



Conclusion

Surface tension and density experiments of four biodiesels and nine fractionated methyl ester reveal the relationship between surface tension and density with temperature. From the experiments, the relationship between temperature dependence and characterization of the effect of chain length upon surface tension and density is also obtained. Four biodiesels have a higher value of density and surface tension other than the nine fractionated methyl ester and petrodiesel as the reason for having higher degree of saturation and more fatty acid content. At the operational temperature (40 °C), the comparison value of density and surface tension between biodiesels and petrodiesel show that biodiesels density and surface tension has a higher value than petrodiesel. Therefore, in terms of diesel engine usage, it is appears that biodiesel samples need to be blended with petrodiesel to obtain a high performance from a diesel engine.

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Appendices

Appendix A - Apparatuses for density and surface tension measurements



Figure A-1: Sigma 702 Tensiometer



Figure A-2: Computer for recording measurement results





Figure A-4: Sample vessel (100 mL)



Figure A-5: Acetone and chloroform for cleaning the tools

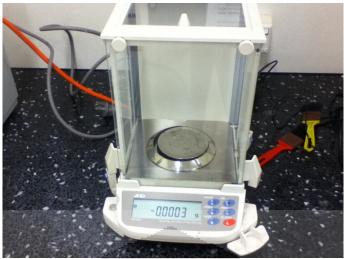


Figure A-6: Precision weighing scale



Figure A-7: B Butane flame

Appendix *B* - Data results for density experiment

Table B-1: Density results for 13 different samples of biodiesels. The density was measured in kg/l.

Waste cooking oil		Tallow		Canola		Cotton seed	
Temperature (Celcius)	Density (kg/l)						
72.8	0.8412	71.5	0.8348	76.9	0.8472	72.5	0.843
59.8	0.8489	58.1	0.8414	63.2	0.8577	58	0.8519
51	0.8507	42	0.845	58.7	0.8586	53.3	0.8625
45	0.855	33.4	0.8528	49.8	0.8658	50	0.8661
42.5	0.8579	33.2	0.8559	44.5	0.8666	44	0.8695
37.5	0.8629	32	0.8594	38.1	0.8686	42	0.8716
33.4	0.8655	28.4	0.863	33.3	0.8747	41.7	0.8731
26.7	0.8707	27.3	0.8646	31.7	0.875	38.9	0.8757
24.4	0.873	25.8	0.8665	26	0.8839	37.7	0.8782
		25.4	0.8675	23.4	0.8856	36.6	0.8788
		24.3	0.8706			35	0.8799
						26.5	0.8843
						24.3	0.8846
						23.4	0.8859
						22.6	0.8878

Pure 121	4	Pure 187	5	Pure 810	
Temperature (Celcius)	Density (kg/l)	Temperature (Celcius)	Density (kg/l)	Temperature (Celcius)	Density (kg/l)
70.2	0.825	72.1	0.8362	70	0.8315
67.1	0.8297	70.8	0.8368	57	0.8416
64.6	0.83	60.2	0.8427	50	0.8455
62.5	0.8339	55.3	0.8435	44	0.8497
58.4	0.835	50.9	0.845	38	0.8545
54.6	0.8393	46.1	0.85	35.9	0.8557
51.7	0.8412	40.7	0.8544	31.2	0.8599
45.8	0.8462	36.6	0.8583	25.8	0.8655
38.8	0.8511	30.2	0.8609		
33.5	0.8555	25.2	0,8647		
28.5	0.8573	22.2	0.8682		Ď
22.8	0.8632		6		3

Main 810		Main 121	4	Main 1875A		
Temperature (Celcius)	Density (kg/l)	Temperature (Celcius)	Density (kg/l)	Temperature (Celcius)	Density (kg/l)	
70.5	0.8281	68.25	0.8308	73.5	0.8325	
64	0.8369	62.5	0.8351	66.3	0.8355	
55.125	0.841	56	0.8384	60	0.839	
48.7	0.8471	50.4	0.8445	56	0.8426	
43.75	0.8521	46	0.8482	51.2	0.8457	
41.3	0.8549	41.05	0.8518	45.5	0.85	
38.5	0.8566	37.65	0.8548	40.1	0.853	
35.8	0.8588	33.4	0.8573	35.2	0.8566	
35	0.859	30.55	0.8591	31.6	0.8607	
31.25	0.8627	25.5	0.8631	24.3	0.8646	
26.4	0.8657	20.6	0.866	21.4	0.8665	
20.5	0.8698					

Mix (810 40.02 g + 1	214 40.02 g)
Temperature (Celcius)	Density (kg/l)
74.1	0.8287
68.7	0.8303
64	0.8354
60.8	0.8371
55.3	0.8412
51.8	0.8448
46.7	0.8493
40.1	0.8552
35.2	0.8579
30.3	0.8614
25.7	0.8643
20.2	0.867

Mix (1214 40.2 g + 1875 A 40.2 g)					
Temperature (Celcius)	Density (kg/l)				
71	0.8318				
65.8	0.8338				
60.8	0.8362				
55	0.8416				
50.7	0.8437				
44.9	0.8482				
40	0.8504				
35.2	0.8575				
30.1	0.8601				
25.8	0.8618				
20.9	0.8665				

Mix (810 40.2 g + 18	75A 40.2 g)
Temperature (Celcius)	Density (kg/l)
78.2	0.828
72.5	0.8299
67.2	0.8338
62.7	0.8383
58.9	0.841
55.4	0.8447
51.4	0.8474
45	0.8518
40.7	0.8532
38.7	0.8567
35.2	0.8603
32.2	0.8615
27.5	0.8643
24.1	0.868
20.6	0.87
The same of the sa	. 1



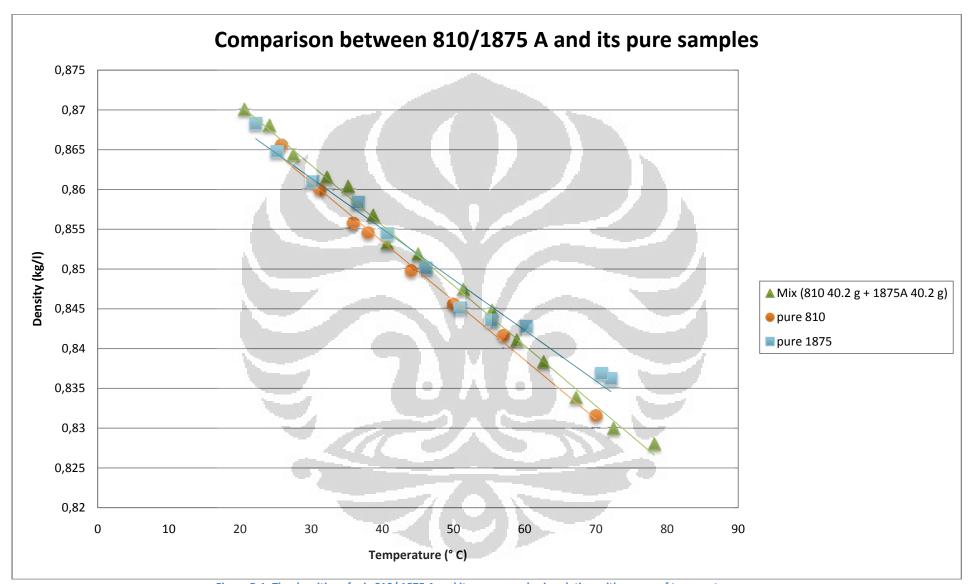


Figure B-1: The densities of mix 810/ 1875 A and its pure samples in relation with ranges of temperature

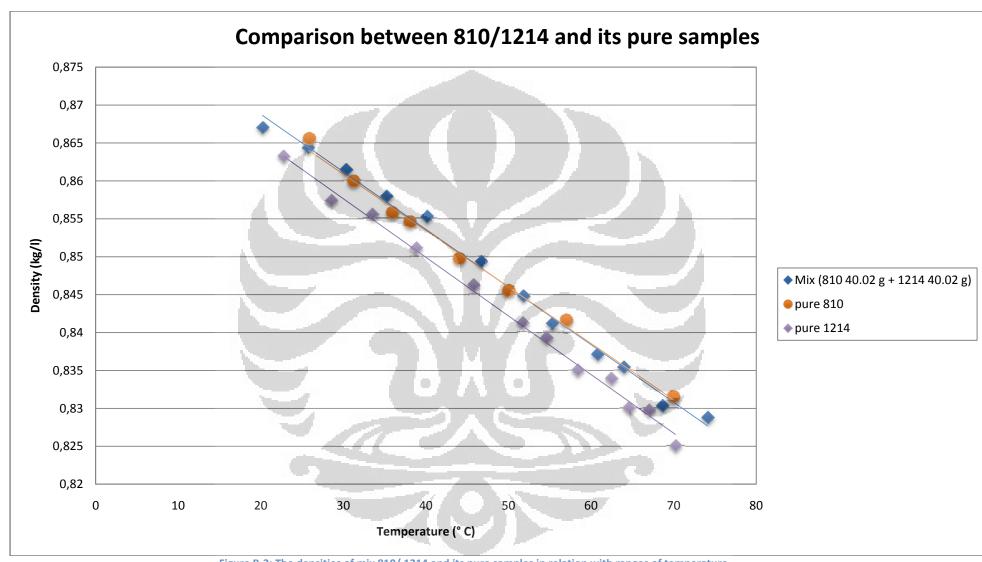


Figure B-2: The densities of mix 810/1214 and its pure samples in relation with ranges of temperature

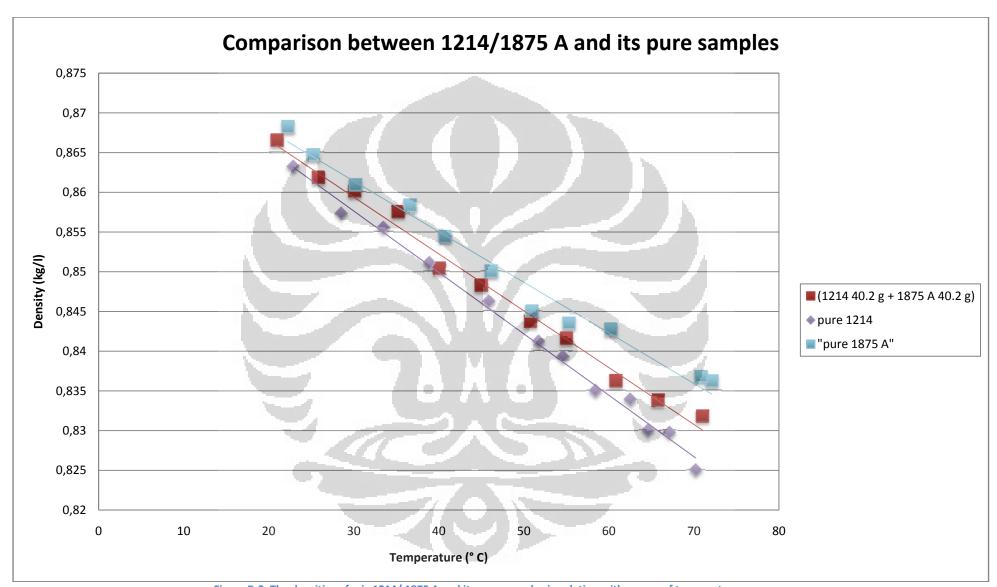


Figure B-3: The densities of mix 1214/1875 A and its pure samples in relation with ranges of temperature

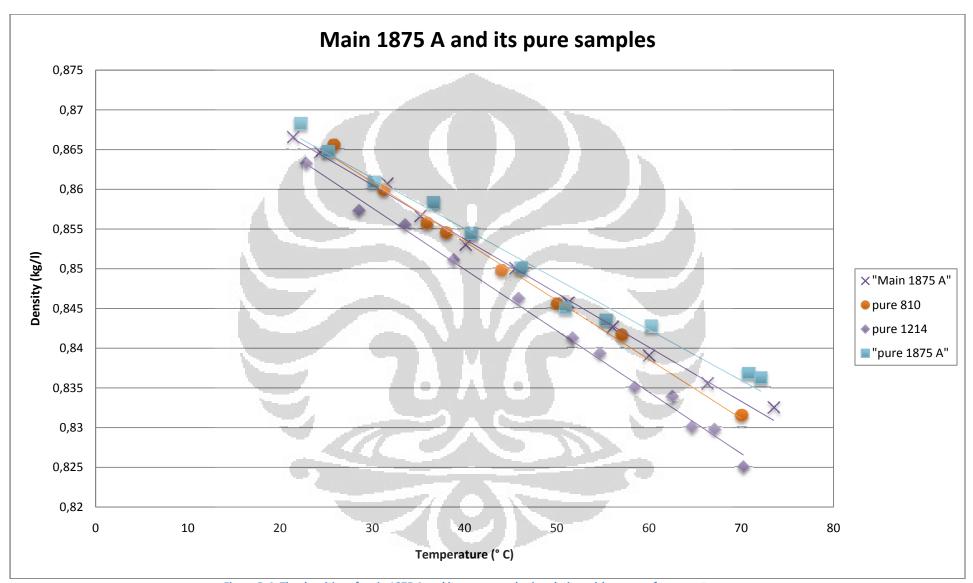


Figure B-4: The densities of main 1875 A and its pure samples in relation with ranges of temperature

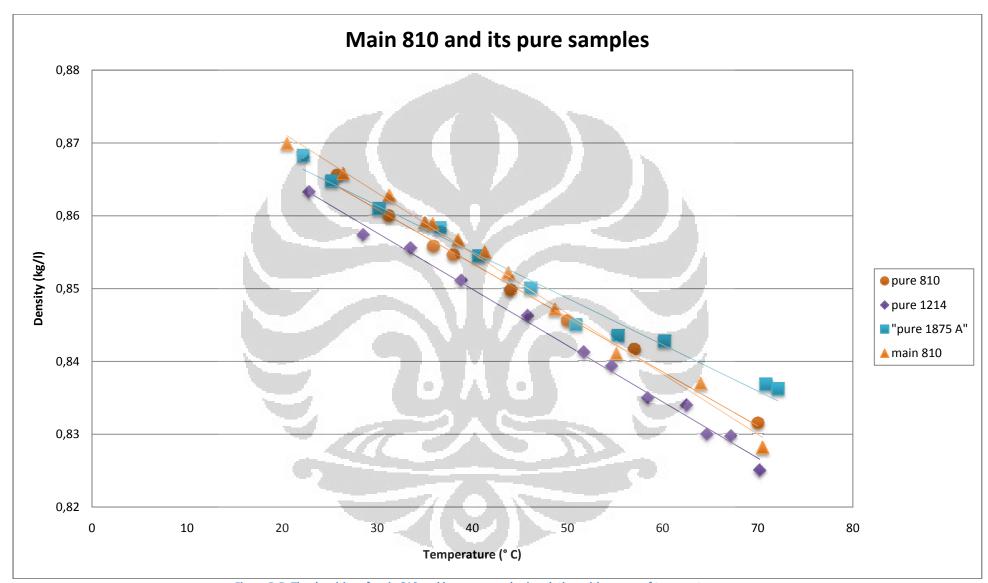


Figure B-5: The densities of main 810 and its pure samples in relation with ranges of temperature

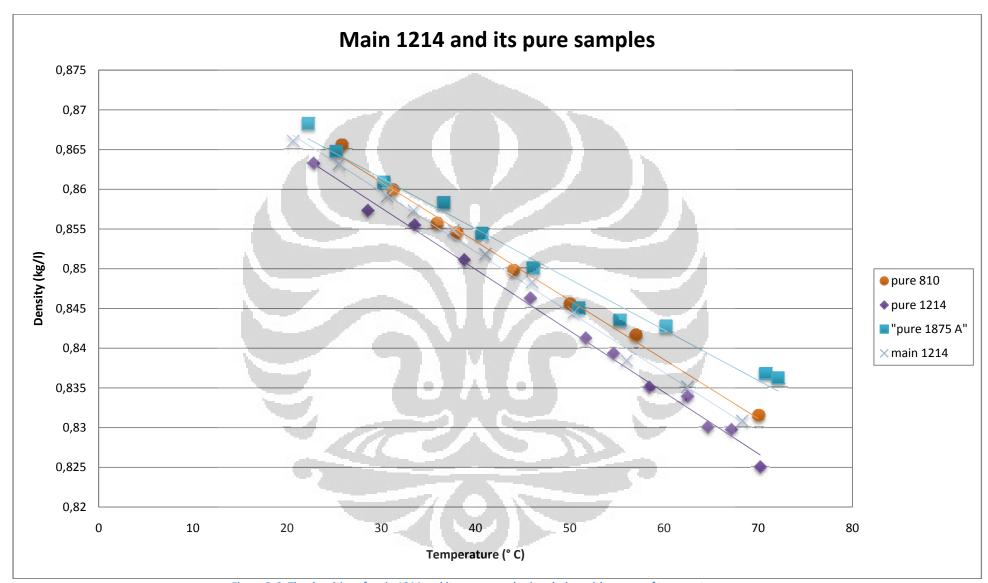


Figure B-6: The densities of main 1214 and its pure samples in relation with ranges of temperature

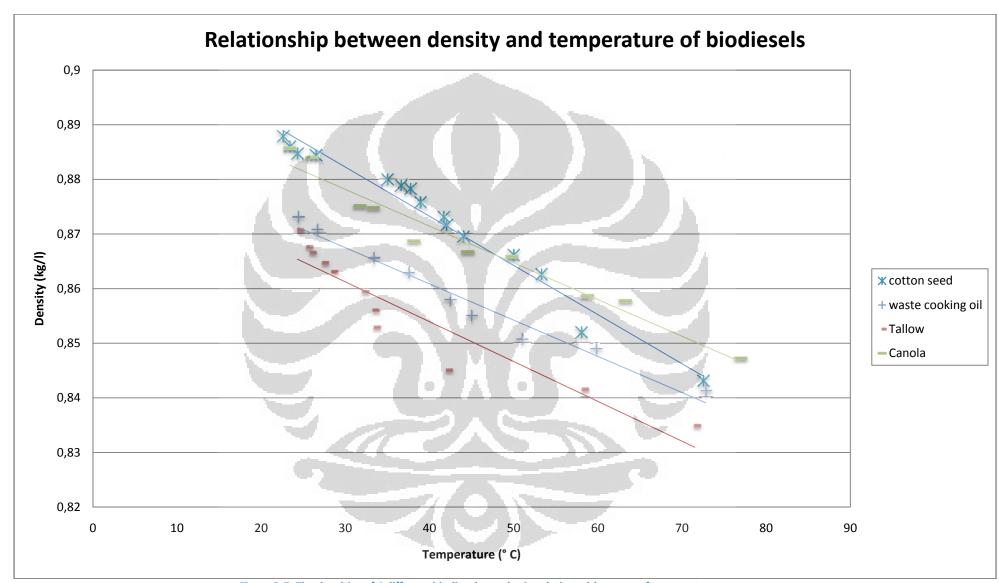


Figure B-7: The densities of 4 different biodiesel samples in relation with ranges of temperature

Appendix *C* – Data results for surface tension experiment

Table C-1: surface tension results for pure 1875 A. The density was measured in mN/m.

Pure 1875 A				
Initial Temp. (Celcius)	Initial Surface Tension (mN/m)	Avg. Temp. (Ceslcius)	Avg. Surface Tension (mN/m)	
72.2	25.82	64.1	25.95	
63	25.86	57.9	25.98	
73.2	26.01	57.6	26.08	
56.4	27.06	52	27.06	
52.8	27.63	48.25	27.64	
46.9	27.82	43.35	27.82	
40.8	28.16	38.6	28.11	
36.6	28.75	34.55	28.7	
31.2	29.05	30.15	29	
26.1	29.68	25.8	29.58	
19.6	30.18	19.6	30.08	
19.1	30.62	19.1	30.5	

Table C-2: surface tension results for pure 1214. The density was measured in mN/m.

Pure 1214				
Initial Temp. (Celcius)	Initial Surface Tension (mN/m)	Avg. Temp. (Ceslcius)	Avg. Surface Tension (mN/m)	
75.9	23.61	69.05	23.7	
69.9	24.27	63.85	24.31	
60	24.47	54.4	24.51	
56.6	25.48	52.1	25.52	
52.5	26.04	48.1	26.04	
46.2	26.27	44.15	26.29	
41.8	26.53	38.9	26.49	
37.3	26.92	35.25	26.84	
30	27.35	29.35	27.24	
24.8	27.93	24.7	27.78	
22.7	28.07	22.7	27.95	
19.5	28.34	19.25	28.21	

Table C-3: surface tension results for pure 810. The density was measured in mN/m.

Pure 810				
Initial Temp. (Celcius)	Initial Surface Tension (mN/m)	Avg. Temp. (Celcius)	Avg. Surface Tension (mN/m)	
72.7	21.95	65.15	22.06	
65.8	22.31	60.25	22.28	
61.4	22.64	56.4	22.66	
54	22.72	51.45	22.87	
50.9	23.02	47.6	23.01	
45.6	23.22	43.1	23.23	
41.7	24.28	39.45	24.26	
35.4	24.69	33.55	24.64	
30.5	25.12	30	24.98	
26.4	25.74	25.9	25.6	
20.2	26.42	20.2	26.32	

Table C-4: surface tension results for canola biodiesel. The density was measured in mN/m.

Canola biodiesel				
Initial Temp. (Celcius)	Initial Surface Tension (mN/m)	Avg. Temp. (Celcius)	Avg. Surface Tension (mN/m)	
72.3	25.64	66.95	25.87	
64.6	26.17	58.6	26.31	
58.7	26.28	55.95	26.41	
54.8	26.83	48.4	26.87	
50.6	27.38	46.55	27.38	
45.5	27.44	42.35	27.43	
40.1	27.7	37.55	27.67	
34.4	27.94	33.2	27.9	
30	28.35	29.3	28.28	
24.5	28.61	24.5	28.51	

Table C-5: surface tension results for waste cooking oil. The density was measured in mN/m.

Waste cooking oil				
Initial Temp. (Celcius)	Initial Surface Tension (mN/m)	Avg. Temp. (Celcius)	Avg. Surface Tension (mN/m)	
74.8	25.65	67.25	25.86	
67.9	25.95	63.55	26.05	
61.5	26.31	55.45	26.35	
56.2	26.63	51.25	26.68	
49.5	26.95	46.4	26.93	
45.8	27.06	44.1	27.01	
40.6	27.16	36.7	27.11	
33.9	27.33	32.7	27.28	
29.8	27.46	29.45	27.48	
25	27.94	25	27.87	

Table C-6: surface tension results for tallow. The density was measured in mN/m.

Sample : Tallow				
Initial Temp. (Celcius)	Initial Surface Tension (mN/m)	Avg. Temp. (Celcius)	Avg. Surface Tension (mN/m)	
75.5	24.46	67.2	24.61	
65.7	25.36	56.7	25.25	
60.3	25.7	51.75	25.38	
47.2	26.08	42.7	26.18	
43.7	26.31	41.05	26.39	
39.3	26.51	35.35	26.57	
35.2	27.12	31.4	27.16	
30.6	27.25	30.2	27.24	
24	28.25	24	28.22	
20.5	28.62	20.5	28.41	

Table C-7: surface tension results for cotton seed. The density was measured in mN/m.

4	Cotton	seed	
Initial Temp. (Celcius)	Initial Surface Tension (mN/m)	Avg. Temp. (Celcius)	Avg. Surface Tension (mN/m)
71.8	24.13	66	23.67
67.2	24.28	63.9	23.84
65.8	24.53	61.3	24.29
61.3	24.97	56.7	24.59
61.8	25.77	54.9	25.67
56.5	25.96	51.35	25.78
51.8	26.52	45.4	26.35
46.5	27.13	41.95	26.94
39.5	27.78	37.75	27.58
34.8	28.13	34.7	28.01
29.5	28.74	28.85	28.54
25.6	29.06	25.6	28.89
21.8	29.11	21.8	28.94

Table C-8: surface tension results for mix 810 + 1214. The density was measured in mN/m.

Sample : Mix 810+1214.				
Initial Temp. (Celcius)	Initial Surface Tension (mN/m)	Avg. Temp. (Celcius)	Avg. Surface Tension (mN/m)	
75	20.8	67.5	21.57	
69.1	21.82	63.75	21.69	
62.6	22.01	58.9	21.79	
50.4	22.16	47.35	22.06	
45.5	22.59	43.15	22.29	
39.2	22.74	37.45	22.88	
35	23.27	33.85	22.93	
31.7	23.52	31.2	23.55	
26.3	23.63	26.3	23.7	
21	26.12	21	26.1	

Table C-9: surface tension results for mix 1214 + 1875 A. The density was measured in mN/m.

Sample : Mix 1214 + 1875A				
Initial Temp. (Celcius)	Initial Surface Tension (mN/m)	Avg. Temp. (Celcius)	Avg. Surface Tension (mN/m)	
78	23.46	72.6	23.52	
70.2	23.93	64.8	23.97	
64.9	24.24	62.1	24.26	
59.8	24.89	55	24.94	
56.4	24.97	53.45	25.02	
51.6	25.44	48.4	25.46	
44.5	25.79	42.15	25.75	
37.3	26.42	35.8	26.36	
32	26.86	31.4	26.77	
25.2	27	25.2	26.94	
22.3	27.6	22.3	27.34	

Table C-10: surface tension results for mix 1875 A + 810. The density was measured in mN/m.

Sample : Mix 1875A + 810			
Initial Temp. (Celcius)	Initial Surface Tension (mN/m)	Avg. Temp. (Celcius)	Avg. Surface Tension (mN/m)
74.2	22.36	67.5	22.46
70.1	22.9	65.65	23
63.5	23.54	58.85	23.56
57.1	23.65	53.5	23.63
54.8	24.27	52.3	24.27
50.4	24.31	48.5	24.31
45.5	24.64	43.7	24.63
35.5	25.74	34.4	25.66
29	26.24	29	26.14
22.4	26.54	22.4	26.43
20.7	27.29	20.7	27.26

Table C-11: surface tension results for main 1875 A. The density was measured in mN/m.

Sample : Main 1875A				
Initial Temp. (Celcius)	Initial Surface Tension (mN/m)	Avg. Temp. (Celcius)	Avg. Surface Tension (mN/m)	
76.5	23.2	72.05	23.33	
67.3	23.33	63.3	23.36	
65.6	23.74	60.5	23.67	
61.1	23.99	58.35	23.96	
58.1	24.25	55.15	24.2	
54	24.5	51.5	24.39	
51.6	25	49.05	24.92	
44.7	25.06	41.05	24.98	
40.8	25.74	39.25	25.67	
35.9	26.09	34.7	25.96	
30.5	26.53	29.65	26.36	
25.4	27.09	25.4	26.96	
21.4	27.82	21.4	27.67	

Table C-12: surface tension results for main 1214. The density was measured in mN/m.

	Sample: Main 1214				
Initial Temp. (Celcius)	Initial Surface Tension (mN/m)	Avg. Temp. (Celcius)	Avg. Surface Tension (mN/m)		
70.6	23.01	65.45	22.99		
64.5	23.23	60.45	23.24		
60.2	23.54	55.2	23.59		
56.7	23.81	53.65	23.8		
51.4	24.07	49.3	24.01		
46.1	24.19	44.2	24.16		
40.8	24.66	39.5	24.58		
36	24.82	34.95	24.76		
29.2	25.27	29.1	25.13		
25.9	25.78	25.9	25.66		
21.8	26.95	21.8	26.95		

Table C-13: surface tension results for main 810. The density was measured in mN/m.

	Main	810	
Initial Temp. (Celcius)	Initial Surface Tension (mN/m)	Avg. Temp. (Celcius)	Avg. Surface Tension (mN/m)
74.7	21.73	68.7	21.85
70.3	21.84	64.45	21.86
66.1	21.92	60.4	21.94
64.8	21.96	57.55	22.01
61.7	22	57.45	22.05
57.2	22.07	53	22.05
55.4	22.12	52.65	22.11
49.9	22.95	43.85	22.94
45.4	23.01	43.6	22.96
41.2	23.7	42.25	23.67
36.4	24.49	35.4	24.38
30.3	25.21	29.5	25.1
25.8	25.46	25.25	25.34
24.7	25.57	25.8	25.46
20.4	26.09	20.4	26.04

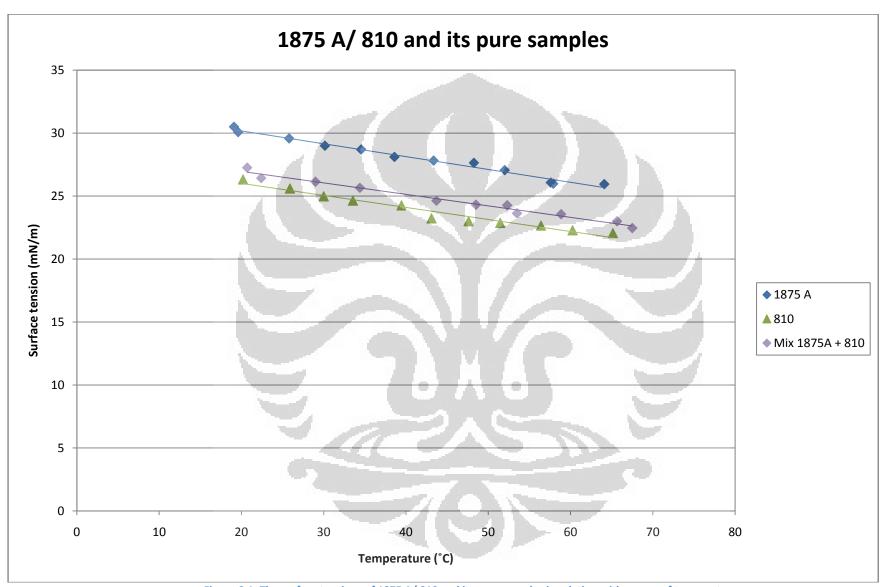


Figure C-1: The surface tensions of 1875 A/ 810 and its pure samples in relation with ranges of temperature

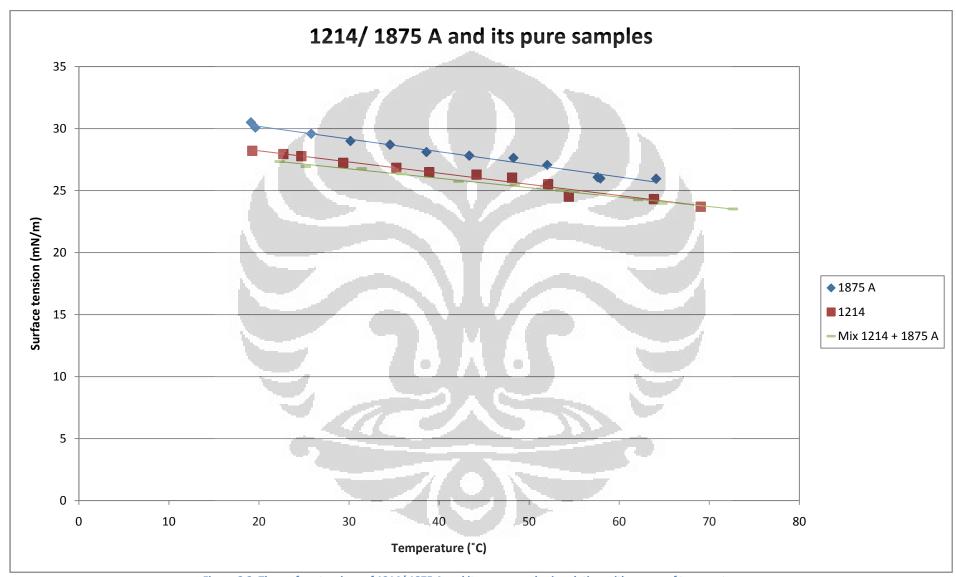


Figure C-2: The surface tensions of 1214/1875 A and its pure samples in relation with ranges of temperature

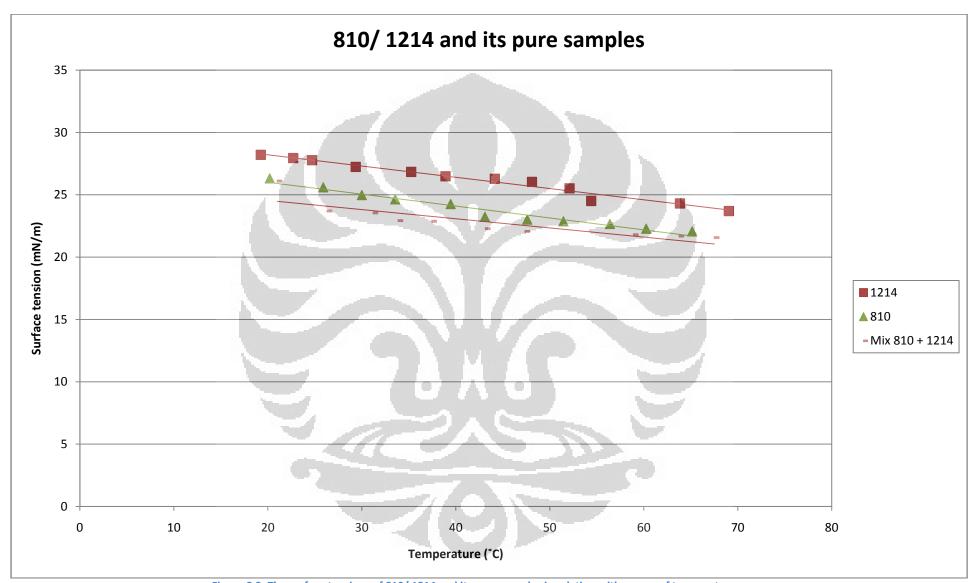


Figure C-3: The surface tensions of 810/1214 and its pure samples in relation with ranges of temperature

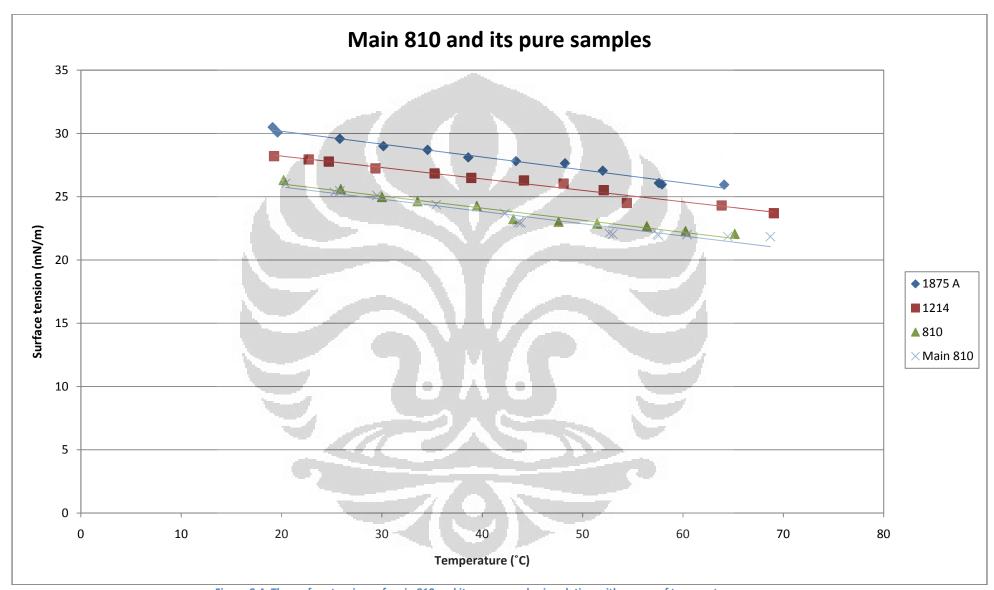


Figure C-4: The surface tensions of main 810 and its pure samples in relation with ranges of temperature

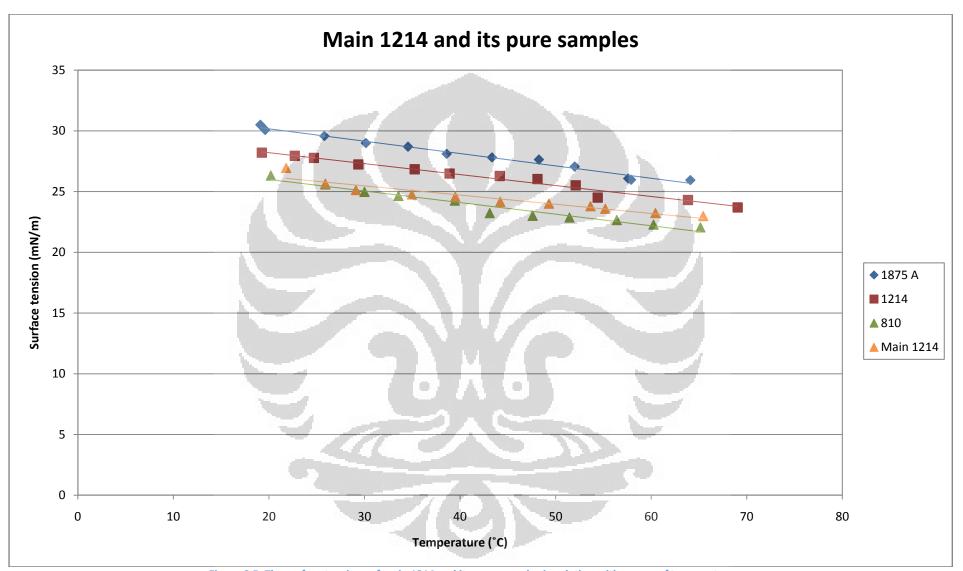


Figure C-5: The surface tensions of main 1214 and its pure samples in relation with ranges of temperature

Figure C-5:

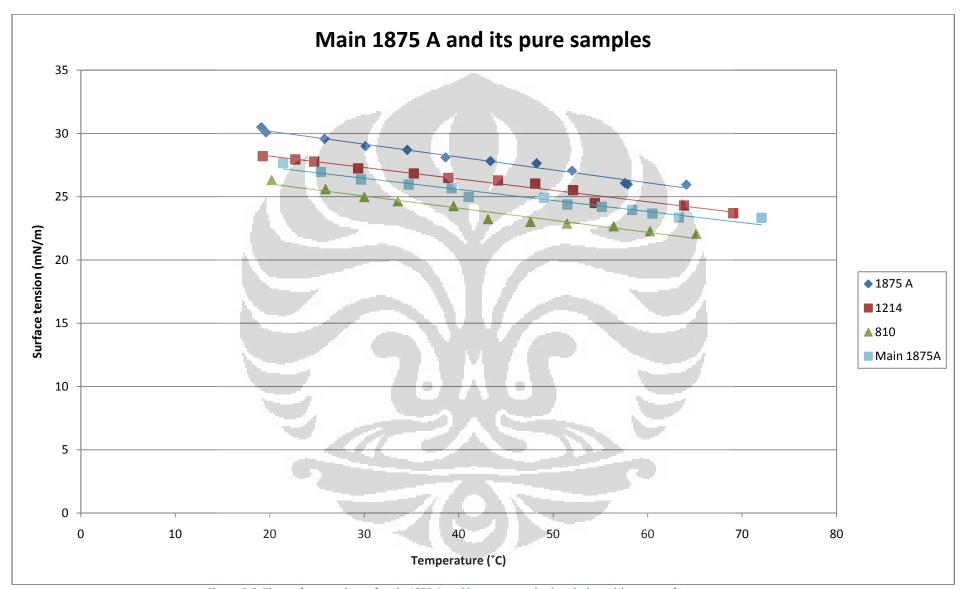


Figure C-6: The surface tensions of main 1875 A and its pure samples in relation with ranges of temperature

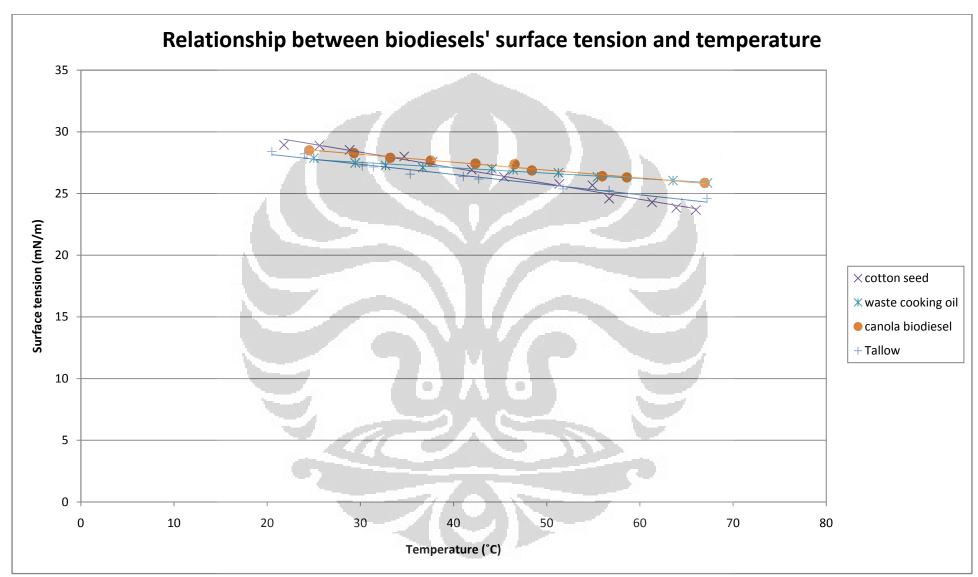
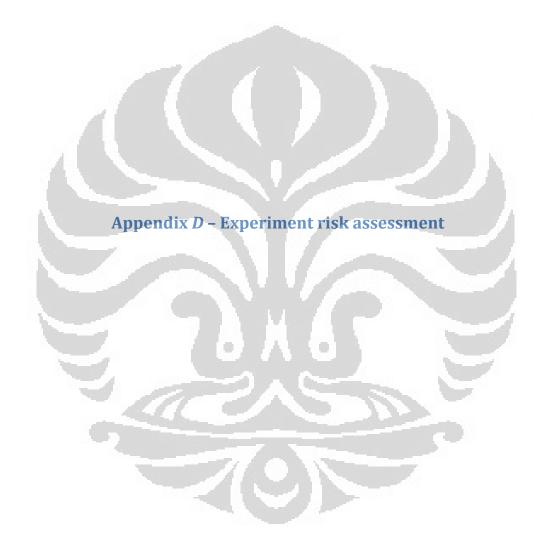


Figure C-7: The surface tensions of 4 different biodiesel samples in relation with ranges of temperature



Project Type (tick appropriate box / boxes)

PG Project (Individual or

Group)

PG Class Project

or Tutorial

PG Research



UG Project

(Individual or Group)

UG Class Exercise

UG Tutorial

RISK MANAGEMENT PLAN

This form consists of a Project Information page and Risk Register. You are required to completeboth pagesand submitfor approval prior to commencing any project.

Site Visit

Field

Activity

Social

The form is linked to the Risk Management Policy and Guide (CP097), which should be read prior to completing this form and contains guidance notes, examples of common hazards, predictable risks and suggested controls.

Use the hyperlinks in this document to access additional information, guidance notes and common project risk details.

<u>Project Title</u>—Experimental Investigation on Surface Tension and Density of Biodiesels as Functions of Temperature

Staff Research

Project

Collaborative

Project

Work Activity

	3 (3)	Project		Networ	king				
Project C	Category (School / Portfoli	o / Discipline)							
	ring Systems iscipline Below)	Design (Specify Discipline Below)	Oline Urban Development (Specify Discipline Below)			Research (Specify Discipline Below)			
					-	40).			
Teachin	g & Learning	Faculty Operations	Exte	rnal Relatio	ns		r (detail elow)		
Other		11	17.		4				
		ails of the exact nature of vign, permit, authority or ot				page)			
			1 4						
This proj	ject examines the surf	face tension and densi	ty of four	biodiese	I fuels an	d nine fract	ionated	met	hyl
ester as	a function of tempera	ture, based on the exp	erimental	perform	ance resu	lt. This proj	ect also	aims	to
find the	relationship between	temperature depende	ence and o	haracter	zation of	the effect	of chair	len	gth
upon sur	face tension and dens	ity. The experiment ha	s been cor	nducted in	the QUT	laboratory,	E block	roor	n E
406, usir	ng a KSV Sigma 70 2 T	ensiometer in order to	o collect t	he data 1	rom all ti	ne samples.	All res	ult d	ata
gained fr	om the experiment ar	e analysed and compar	ed with th	e results	from curr	ent literatur	e.		
		40							
Does you	ır project involve workiı	ng with electricity <u>above</u>	50V AC or	120V DC (Extra Low	Voltage)	<u>YES</u>	NO	X
HELP	Project Location : QU' (site, room, etc)	T Gardens Point Room E	406			posed comm 14/12	nenceme	nt da	ite
		Names:		Student		Contact Ph		bile	N0.
Project T	eam Members names	Jagaddhita Pandya At	=	N7266219		0451231905			
Contact p	phone/mobile numbers D No. If applicable	Fadil Wimala Darmanto		N7266375 044970373		044970373	30		
	(Attach list if necessary)								
		Name/s			Phone No.				
	upervisor/s	1. Associate Professor Richard							
(Name &	Phone number)	Brown 2. Muhammad Ja	2. +61413809227 (MJ Islam)			m)			
D. 1.1									

Asset / Equip Procurement

Corporate Level Project

Commercial Project

Overseas

Domestic

Valid to / Review by (Insert DATE)	Actual Review Date	Reviewed By (Please Print)	Signature





Use the hyperlinks in this document to access additional information, guidance notes and common project hazards, risk & controls contained in CP097.

Risk Assessment and Risk Register

(How to conduct a Risk Assessment)

No	Hazard, Activity, Task, or Process (Go to Hazard Categories) Electricity (Experiment requires the use of appliances with electricity)	- Electric shocks or burns (50 volts AC or 120 volts DC are considered hazardous) - Fire (Electrical faults can cause fires) - Flammable (electricity can be a	Risk Level Initial	Proposed Control Measures (All control measures must comply with legislative requirements and follow the Control Hierarchy. - Wear shoes - Keep an eye on plugs, sockets, cables, and electrical connections Identify the locations of switches and emergency OFF buttons to cut off power in an emergency	Residual Risk Level Final	Notes / Remarks 1) Who is responsible to implement controls? 2) Latest implementation date? 3) Other relevant detail. 1) Lab users 2) 26/04/12 3)
2	Heater (The experiment requires the biodiesel samples to be heated from room temperature to 80 degrees celcius)	source of ignition in a potentially flammable atmosphere. - Fire - Burn injuries	ЗН	Identify the locations of fire extinguishers Check the condition of the equipment and power cords for obvious damage Never leave the equipment unattended during the experiment	2M	1) Lab users 2) 26/04/12 3)
3	Chemicals (acetone is required for cleaning sample container)	 Irritating to the eyes (worst case can cause blindness) May cause fatal lung damage if swallowed Skin damage Explosion hazard Fire (highly flammable) Spillage 	4A	- Identify the locations of safety shower and eye wash - Wear lab goggles - Wear lab jackets - Wear gloves - Cautious handling - Avoid the chemicals from sources of ignition - Spills must be clean up immediately (if occurs)	2M	1) Lab users 2) 26/04/12 3)
4	Biodiesel samples (the densities of these samples at different temperature will be measuredusing KSV Sigma 702)	 Spillage Flammable (Flash points at >100°C) 	3H	Adequate biodiesel storage Careful handling Limit the heating of biodiesels to 80 degrees celcius	1L	1) Lab users 2) 26/04/12 3)
5	Water (from water tap)	 Leakage Slip and fall accidents Wet environment (can attribute to electrical hazards) 	3H	- Make sure water taps are properly closed when not used - Wipe hands and water spots after using the water tap	1L	1) Lab users 2) 26/04/12 3)
6	Laboratory gas systems (will not be used for the experiment)	LeaksFireChemical hazards	4A	- Identify the shutoff system - Keep the tap closed	2M	1) Lab users 2) 26/04/12 3)

Risk Assessment	Name (Print)	Appointment	Student No(If Applicable) N7266375 (Fadil)	Signature	Date
Conducted By (Author)	Fadil Wimala Darmanto				26/04/12
	Jagaddhita Pandya Atmaja		N7266219 (Jagad)		

I certify that I have consulted with appropriate personnel and have considered professional advice and/or relevant information in conducting this assessment and have obtained necessary approvals, permits, licences as applicable to the project.

APPROVALNote> Individuals approving this document accept responsibility for the appropriateness of controls and for the validity of the Risk Management Plan.

	Name	Appointment / Title	Signature	Date
Approved By	(PRINT)			

Distribution:

- Original (Hard Copy) held by Author for duration of project and must be available to management, health and safety personnel, WH&S QLD Inspector or other authorised person on request.
- Electronic or Hard Copy held by Approver for the duration of the project.
- Electronic (preferred) or Hard Copy forwarded by Author to Faculty Health & Safety Section m.goddard@qut.edu.auRoom S1124 GPwithin 7 Days of approval.

Risk Calculator

Return to Risk Register

	Consequences: How severely it hurts someone (if it happens)?							
Likelihood: How likely is it to happen?	Insignificant (no injuries, no damage)	Minor (first aid treatment only; damage / spillage contained at site)	Moderate (medical treatment; damage / spillage contained but with outside help)	Major (extensive injuries; loss of production; significant impact)	Catastrophic (death; toxic release of chemicals; extensive damage)			
Almost certain – expected to occur in most circumstances	3 H	3 H	4 A	4 A	4 A			
Likely – Occurs frequently in most circumstances	2 M	3 H	3 H	4 A	4 A			
Possible – Has been known to occur in certain circumstances	1 L	2 M	3 H	4 A	4 A			
Unlikely – could occur at some time but improbable	1 L	LOM	2 M	3 H	4 A			
Rare - may occur but only in exceptional circumstances	i -		2 M	3 H	H H			
Score and Statement	core and Statement Action							
4 A: Acute	ACT NOW to eliminate or reduce risk – URGENT - do something about the risks immediately. Refer to management if outside your scope to control. Proceed only with the greatest caution.							
3 H: High	Implement controls to remove or reduce the risk before proceeding. Refer to management if outside your scope to control. Seek advice, stay focused and remain aware.							
2 M: Moderate	Proceed with caution and monitor progress closely. Follow safe work procedures. Stay focused and remain aware.							
1 L: Low	Proceed with activity. Record and review if any equipment/ people/ materials/ work processes or procedures change. Remain aware.							

How do you assess the level of risk using this calculator?

- 1. Consider the possible <u>Consequences</u> should the risk eventuate (How severely could it hurt someone how much damage could it cause if it happens?)
- 2. Consider the <u>likelihood</u> of risk eventuating under the stated circumstances (apply knowledge and experience of the risk and/or obtain advice from someone who knows)
- 3. Marry the two to arrive at the Risk Level

What do you do about it?

- If this is your Initial Risk Level, apply existing controls or develop controls to eliminate or reduce the Risk Level (Refer <u>Hierarchy of Controls</u>)
- 2. Re-assess what the Risk Level will be after the controls are applied (Residual Risk Level)
- 3. Carry out the Action Required for the Residual Risk Level as per the table above

NOTE If you intend working on an *energised* electrical circuit above Extra Low Voltage (ELV) you must follow the procedure listed in <u>CP150</u> (Electrical Work Live). Failure to do so will result in a serious safety breach with severe consequences. If you are not sure that live electrical work is involved in your project, consult the Electrical Laboratory Supervisor or the Faculty Health and Safety Section <u>before proceeding</u>.

