EXPERIMENTAL ON SULFUR REDUCTION PROCESS FOR WASTE PRODUCT AND BIODIESEL FUEL

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May 2018

This dissertation is submitted to
Universiti Sains Malaysia
As partially fulfilment of the requirements to graduate with honors degree in
BACHELOR OF ENGINEERING (MECHANICAL ENGINEERING)

School of Mechanical Engineering
Engineering Campus
Universiti Sains Malaysia

Declaration

This work has not previously been accepted in substances for any degree and is not being concurrently submitted in candidature for any degree.

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Date :

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Acknowledgements

This thesis becomes a reality with the kind support and help of many individuals. I would like to extend my sincere thanks to all of them.

Foremost, I am very grateful to GOD ALMIGHTY for His graces and blessings upon me, without Him, this study would not have been possible.

Special thanks to Prof. Dr. Zainal Alimuddin Zainal Alauddin, Dean of School of Mechanical Engineering, USM and Dr. Mohamad Ikhwan Zaini Ridzwan, Final Year Project coordinator for giving the opportunity and support to finish this research. I learnt so many things while doing this research.

Immeasurable appreciation and deepest gratitude for the help and support are extended to Prof. Ir. Dr. Mohd Zulkifly Abdullah, my beloved supervisor for his guidance and help while doing my research. His knowledge in this field helps me a lot.

Next, I am most grateful to Mr. Nor Ridwan bin Mohamed Yusuf, assistant engineer of School of Aerospace Engineering for his guidance and technical support. He helped me a lot on the setup of the experiment and always give me support in finishing my research.

Last but not least, I am very thankful to have supportive friends and family that always give me advice and help on this research and thesis writing. They are my inspiration to pursue this undertaking.

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List of Abbreviations

ASTM	American Society for Testing and Materials
Al	Aluminium
Ca	Calcium
CD	Catalytic distillation
CPO	Crude palm oil
C_2H_5OH	Ethanol
EDXRF	Energy-dispersive X-ray fluorescent
EPA	Environmental Protection Agency
Fe	Iron
FFA	Free fatty acid
GTW	Grease trap waste
HCV	Higher Calorific Value
H_2SO_4	Sulfuric acid
ICP-AES	Atomic emission spectrometry
ICP-OES	Inductively coupled plasma atomic emission spectroscopy
ID-SF-ICP-MS	Isotope dilution and sector field inductively coupled plasma mass spectrometry
KOH	Potassium hydroxide
Mg	Magnesium
N	Nitrogen
NaOH	Sodium hydroxide
P	Phosphorus
S	Sulfur
SO_2	Sulfur dioxide
USM	Universiti Sains Malaysia
XRF	X-ray fluorescent
XPS	X-ray photoelectron spectroscopy
Zn	Zink

Nomenclature

Tcorr	Temperature correction	^{o}C
HCV	Higher Calorific Value	J/g

Abstrak

Kajian ini dibuat untuk menyelesaikan masalah kandungan sulfur yang tinggi dalam bahan bakar biodiesel yang bergred rendah seperti minyak sawit mentah, minyak masak sisa dan minyak enjin sisa. Kandungan sulfur yang tinggi dalam bahan bakar biodiesel yang digunakan dalam enjin diesel boleh menjejaskan alam sekitar kerana sulfur dioksida (SO_2) dilepaskan ke sekitar apabila pembakaran berlaku. Untuk menyelesaikan masalah ini, proses yang dapat mengurangkan kandungan sulfur dalam bahan bakar biodiesel yang bergred rendah iaitu proses penyulingan vakum dibuat. Ujian Elemental Analyzer dibuat untuk mengukur kandungan sulfur dalam produk penyulingan. Dari hasilnya, kandungan sulfur dalam minyak enjin sisa dikurangkan sebanyak 11.95% sementara yang lainnya memiliki hasil negatif. Ini membuktikan bahawa, proses penyulingan vakum telah mengurangkan kandungan sulfur lebih daripada 10% daripada nilai asalnya. Untuk mengukur nilai kalori, ujian Bombcalorimeter dijalankan ke atas produk penyulingan. Hasil yang ditunjukkan, Nilai Kalori Tinggi (NKT) meningkat kira-kira 0.82% untuk minyak sawit mentah (CPO) manakala 0.19% untuk minyak enjin sisa dan untuk minyak masak sisa menunjukkan nilai negatif. Oleh itu, sulfur boleh dikeluarkan dalam minyak enjin sisa oleh proses penyulingan vakum kerana ia mempunyai hasil positif dari Analisis Elemenal dan ujian Bombcalorimeter. Kajian ini dapat diperbaiki dengan menambah proses lain seperti pencucian asid, pengekstrakan pelarut, esterifikasi, dan transesterifikasi dalam pengeluaran biodiesel untuk memastikan lebih banyak sulfur dikeluarkan.

Abstract

This research is made to solve a problem of the high sulfur content in the lower grade biodiesel fuel such as the crude palm oil, waste cooking oil, and waste engine oil. High sulfur content in the biodiesel fuel that used in diesel engine may affect the environment as the sulfur dioxide (SO_2) is emitted to the surrounding when combustion occur. To solve this problem, a process that able to reduce sulfur content in a lower grade biodiesel fuel which is the vacuum distillation process is developed. An Elemental Analyzer test is made to quantify the sulfur content in the product of distillation. From the result, the sulfur content in the waste engine oil is reduced as much as 11.95 % while the others have the negative result. This proved that, the vacuum distillation process has reduced the sulfur content of more than 10% of its original value. To quantify the calorific value, Bombcalorimeter testing is conducted on the distillation product. The result shown, the Higher Calorific Value (HCV) is increased about 0.82 % for crude palm oil (CPO) while 0.19 % for waste engine oil and for waste cooking the result shows the negative value. Thus, the sulfur can be removed in the waste engine oil by the vacuum distillation process as it has a positive result of Elemental Analysis and Bombcalorimeter testing. This study can be improved by adding other processes such as the acid washing, solvent extraction, esterification, and transesterification in biodiesel production to make sure more sulfur is removed.

CHAPTER ONE

1 Introduction

This chapter gives a general introduction to the topics of this research which included about the effect of sulfur to the environment, sulfur in biodiesel, advantages of biodiesel and the biodiesel production. Problem statement in this chapter gives brief descriptions about the problems that must be solved to get the results for this research project. From the problem statement, the research objectives and scope of works are defined and will be discussed.

1.1 Brief Overview

Sulfur with symbol S in the Periodic Table of Element is a chemical element that is necessary for life, specifically for plants, animals and humans. Sulfur, which is the third most abundant mineral in the human body, also very useful in the manufacturing process such as in the production, preparation and preservation of products. It can be found in the soil, plants, food and water. Despite of its plentiful of advantages, sulfur also has its disadvantages which are mostly in the form of sulfur dioxide (SO_2) and hydrogen sulfide (World Health Organisation, 2004). The damaging sulfur bonding will cause environmental quality to be affected because of its toxicity. Sulfur dioxide in the form of gas, which was emitted from the fossil fuel combustion by the vehicle or industry can cause acid rain when reacts with other chemicals. Acid rain will damage buildings, forest and crops, increase the acidity of the river and lake and thus kill the living creatures (USEPA, 2015).

Sulfur also available in biodiesel fuel, but must not exceed 15 ppm according to the Environmental Protection Agency (EPA) regulations starting from 1 June 2006 (He et al., 2009). This is to ensure the low sulfur dioxide emission to the environment. Biodiesel is an alternative fuel for diesel engines that currently available which is non-toxic and biodegradable. It can also be used directly or blended with petroleum diesel in any proportion such as 100% biodiesel is labelled as B100, 20% biodiesel and 80% petroleum diesel is referred as B20, 5% biodiesel and 95% petroleum diesel is referred as B5 and the least proportion of biodiesel is 2% which is referred to B2. There is no engine modification required for using the biodiesel fuel, but only in winter situation special systems are required as the biodiesel thickens easily in cold condition and turns to gel like texture (Tech, 2016).

Biodiesel, which is renewable energy and clean fuel made from waste vegetable oils, and animal fats (Bio, 2006), which then reduce the waste disposal from the restaurant, and also the pollution in the drainage of the residential areas. By using biodiesel in an engine, about 94% of cancer risks can be reduced (National Renewable Energy Laboratory, 2015) as the low sulfur dioxide emission from the combustion in the engine. The process of making a biodiesel fuel involves a chemical reaction and it is often produced by three basic processes which are based catalyzed, direct acid catalysed transesterification and conversion of the oil to its fatty acids and then to biodiesel. In other words, the reaction is,

$$\text{Oil} + \text{Alcohol} \rightarrow \text{Biodiesel} + \text{Glycerin}$$

1.2 Problem Statement

Sulfur content in a low-grade biodiesel is very high and can reach up to 15000 ppm based on (B. He, 2009). As a result, biodiesel with high sulfur content cannot be sold as it can harm the environment. The sulfur content in a biodiesel fuel must comply with the Environmental Protection Agency (EPA) regulations which is lower than 15 ppm following the standards of the American Society for Testing and Materials (ASTM). Higher sulfur content in the fuel can affect the environment as it can cause acid rain, where acid rain can cause deforestation, acidify waterways to the detriment of aquatic life and corrode building materials and paints. Thus, process to reduce sulfur content in a lower grade biodiesel (crude palm oil, waste cooking oil, and waste engine oil) needs to be developed to treat the biodiesel with high sulfur content so that the biodiesel saves for the environment and can be sold.

1.3 Objectives

The objectives of this experiment are:

1. To develop a process that able to reduce sulfur content in a biodiesel fuel.
2. To reduce sulfur content in a biodiesel fuel for at least 10% of its original value.
3. To test other biodiesel with different sulfur content to ensure the effectiveness of the process.

1.4 Scope of the Project

- Set an experiment of vacuum distillation process for lower grade biodiesel, which are crude palm oil, waste cooking oil and waste engine oil by using the Sulphur Removal Modul.
- Send the samples of the product from the experiments to the School of Chemical Engineering, USM to analyze the sulfur content after the experiment using the Elemental Analyzer and calculate the percentage of sulfur reduction to its original value.

- Test the sample of product from the experiment with Bomb Calorimeter to get the calorific value for each sample.

CHAPTER TWO

2 Literature review

The literature review considered a few topics including the sulfur effect on the environment, biodiesel fuel feedstock, process of biodiesel fuel production, process of removing sulfur in biodiesel production and sulfur content determination. All topics are related to this project.

2.1 Sulfur effect on environment

Sulfur in term of sulfur dioxide (SO_2) gas is mostly produced by the vehicle engine which used fuel with high sulfur content. SO_2 has dangerous effect to the environment and also the living creatures. As in a journal by (Varshney et al., 1979) which proposed that SO_2 gas will affect the trees by disrupting the photosynthesis process when the photosynthetic mechanism is being disturbed. The SO_2 gas also promoted the opening of stomata and thus resulting in loss of water. The same as the research by (KROPFF, 1987) which stated that the photosynthesis process rates is reduced when exposed to the SO_2 gas.

As can be seen in (Setterstrom, 1940) study, SO_2 gas not only affecting the plant, but also animals. The journal by (Brown et al.,2003) proposed that most of the respiratory disease caused by the exposure to the SO_2 gas as the same as the study by (Zhang et al., 2013) high concentration of SO_2 gas will potentially damage the heart as it has been tested on rat's heart. From the reading of the journals, it is proved that the SO_2 gas that produced by the combustion of fuels with high sulfur content will give negative effect to the environment and living creatures.

2.2 Biodiesel fuel feedstock

Waste product always been thrown away as people think it is not useable but waste product such as waste cooking oil, waste engine oil, and many more can be used as biodiesel feedstock. As in the study by (Kobayashi et al., 2017) and (Tu et al., 2017) that proposed the restaurant grease trap waste (GTW) can be used as an alternative to liquid fossil fuels and natural gas and the result shows that the biofuel was produced by the GTW at a very high efficiency. Waste cooking oil also used as biodiesel feedstock as in (Bilgin et al., 2015) study. The study by (Arpa, Yumrutas, & Demirbas, 2010) , (Maceiras, Alfonsín, & Morales, 2017) and (Beg et al., 2010) used waste engine oil as the biodiesel feedstock. The research by (Khalid et al., 2017) and (Alkabbashi et al., 2009) used crude palm oil while the study by (Abdullah et al., 2017) used palm oil sludge which is the waste of the crude palm oil as the feedstock in biodiesel production. Thus, waste cooking oil, crude palm oil and waste engine oil is easy to get and can be used for this research.

2.3 Process of biodiesel fuel production

Demand for the fossil fuel increased recently as the usage of this fuel for the vehicle engine increased year by year. That problem leads many researchers to find alternatives that can replace the fossil fuel which is on the wane. Biodiesel fuel is one of the alternatives that being studied. There are many researchers that study about the biodiesel production, including the study by (Gaurav et al., 2016) which proposed the production of the biodiesel from waste oil using catalytic distillation (CD). This study used green reactor that combines a catalytic reaction and separation via distillation in a same distillation column and the result shows that the production of the biodiesel fuel from yellow grease which containing triglyceride and free fatty acid. Next, the research by (Zaher & Soliman, 2015) proposed that the production of biodiesel by direct esterification of fatty acids with the used of propyl and butyl alcohols as the same as (Abdullah et al., 2017) that proposed the conversion of palm oil sludge into biodiesel by esterification and transesterification process which used methanol and KOH as the reactant. Their studies do not focus on the sulfur reduction of a biodiesel fuel. The research by (Tu et al., 2017), also proposed about the use of crude glycerin for the glycerolysis process in a biodiesel production as the glycerolysis is one of the potential alternative pretreatment method for high free fatty acid (FFA) containing oils. Glycerolysis has the potential advantages of utilizing crude glycerin, and also eliminating the use of hazardous chemicals, such as H_2SO_4 and methanol compared with the acid-catalyzed esterification process. The results from this research shows that the biodiesel production from glycerolysis-treated oil was less energy intensive of biodiesel produced than that from the conventional esterification and transesterification route. Furthermore, the research by (Bilgin et al., 2015) aims of the process of transesterification to produce lowest kinematic viscosity waste cooking oil biodiesel by using sodium hydroxide (NaOH) as a catalyst and ethanol (C_2H_5OH) as the alcohol. The same goes to (Arpa et al., 2010) and (Maceiras et al., 2017) which proposed the production of diesel by pyrolytic distillation while the research by (Ma et al., 2016) and (Bi et al., 2015) used all process including esterification, transesterification, acid washing base washing and lastly vacuum distillation. There are many processes that proposed by the researcher in order to produce biodiesel fuel, but only the research by (Ma et al., 2016) and (Bi et al., 2015) focused on the process that remove the most sulfur in a biodiesel fuel.

2.4 Process of removing sulfur in biodiesel production

Low sulfur content in a biodiesel is required in a biodiesel production as enshrined in the Environmental Protection Agency (EPA) regulations. The process of lowering the sulfur content in a biodiesel fuel is always be the topic to be studied by the researcher. As in the research by (Ma et al., 2016) proposed a novel process for low-sulfur biodiesel production from scum waste. The combination of solvent extraction and acid washing as pretreatment, proved to lower the sulfur content. 70% of filtered and dried scum converted to biodiesel that has low sulfur content which is less than 15ppm. In the solvent extraction process, heptane has the highest efficiency to remove sulfur. From raw scum, which has a higher sulfur content, undergoes acid washing, heptane washing, glycerine esterification, transesterification and distillation processes gives the lower value of sulfur content of about 13.3 ppm. But the previous research that link with the above research, (Bi et al., 2015) also proposed about novel process from wastewater scum to biodiesel fuel that have been demanded. The process involved is still the same as the above journal, but only for the solvent washing which do not implement in this study. The step begins with warming and filtering process and then acid washing with sulfuric acid, separation and drying, acid catalyzed esterification using methanol, base catalyzed transesterification, glycerol wash and lastly distillation. This time, the process is more complicated and time consuming. The result shows that, the sulfur content in the biodiesel produced is higher than the result by (Ma et al., 2016). From the two journals that have been read, the process which has the highest sulfur removal is distillation process.

2.5 Sulphur content determination

Sulfur in biodiesel cannot be determined by naked eyes or by calculation. There are several ways to determine the sulfur content in a biodiesel fuel. Most studies used wavelength X-ray fluorescence (XRF) spectrometry to determine the sulfur content in fuels as in (Barker et al., 2008) , (Bajia et al., 2017) and (Lydia Baker et al, 2016) but the study by (Flahaut et al., 2017) used X-ray photoelectron spectroscopy (XPS) technique while (Miskolczi et al., 2006) used energy-dispersive X-ray fluorescent (EDXRF) and inductively coupled plasma atomic emission (ICP-OES) spectroscopy to determine the sulfur content and the results of those techniques are compared. The research by (Amais et al., 2014) and (Faber, 2017) is a bit different from the other. The study by (Amais et al., 2014) used isotope dilution and sector field inductively coupled plasma mass spectrometry (ID-SF-ICP-MS) while (Faber, 2017) used all of the above techniques including inductively coupled plasma optical or atomic emission spectrometry (ICP-OES, ICP-AES) and wavelength or energy dispersive X-ray fluorescence (XRF, ED-XRF) and thus the comparison is made. Thus, the best technique to determine the sulfur content is chosen based on the quality of the result and the ease of processing.

CHAPTER THREE

3 Proposed solution/Methodology

This chapter presents the discussion and the flowchart of the process that involve in this experiment in order to get the result. After conducting the experiment following the methodology, the data will be presented.

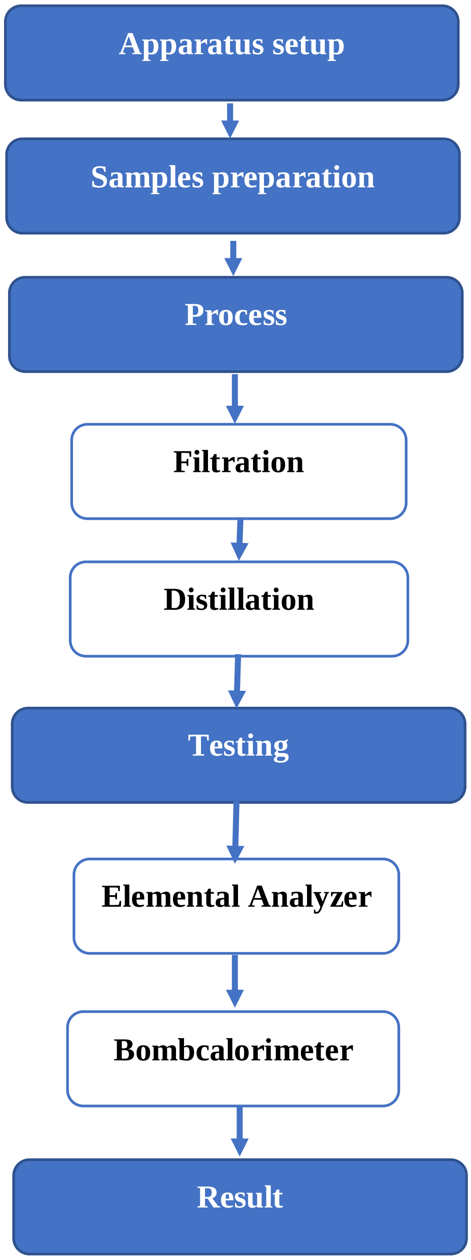

Figure 1 : Summary of procedure involved.

3.1 Samples preparation

There are four samples of biodiesel that have been prepared which are waste cooking oil, waste engine oil, crude palm oil (CPO) and Singapore biodiesel. Singapore Biodiesel that has low sulfur content will act as the reference for this experiment as the sulfur content in it is lower than 10ppm which is considered as ultra-low sulfur diesel (Reuters Staff, 2012). Waste cooking oil sample is easily obtained from the restaurant and the house as the palm cooking oil always been used in Malaysia for frying purpose. Waste engine oil is obtained from Engine Laboratory at School of Mechanical Engineering, USM as the same as the Singapore Biodiesel, while sample of crude palm oil is obtained from the Biomass Laboratory at School of Mechanical Engineering, USM. The crude palm oil must be stirred first as the accumulated sediment at the bottom part is not well mixed. The samples are put in clear containers and labelled.

3.2 Apparatus setup

The important machine that will be used in this experiment is the Sulfur Removal Modul. Equipment that involve in this experiment are, heater, filter paper, vacuum pump, 2000ml beaker, 250ml two necks round bottomed flask, distillation column, syphon tubes, small aquarium pump, connecting tube, stop cork, thermocouple, multimeter, retort stand with clamps, and pail.

Paraffin oil is put into the beaker as shown in Figure 2 and it is used to boil the lower grade biodiesel. The setup of all the equipment is shown in Figure 3. The pail is used to put the water that flows through the distillation column via syphon tube. The flow is pumped by the small aquarium pump. Other than that, steel wool and activated carbon in the form of sand like is packed into the distillation column.

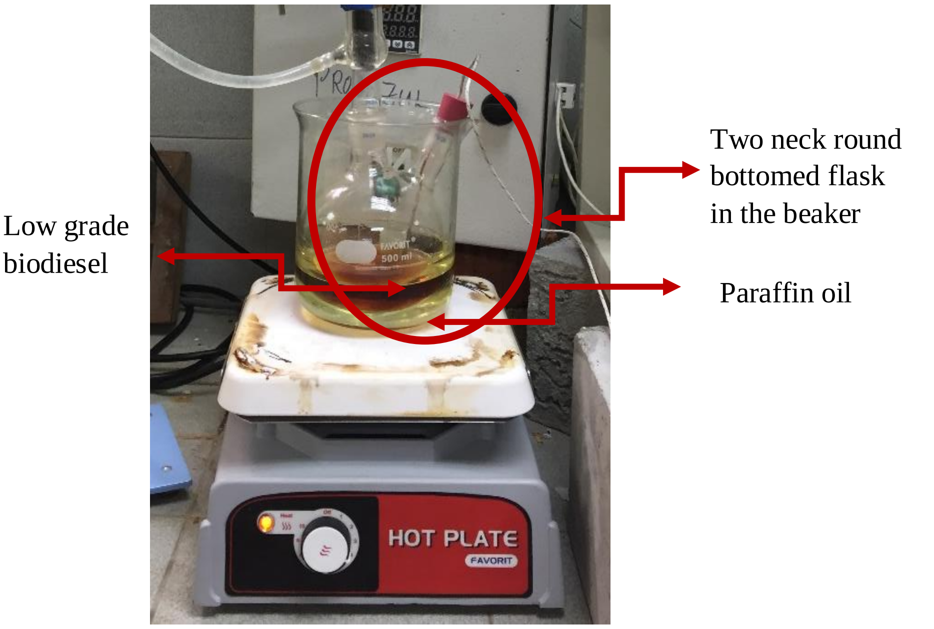

Figure 2 : The setup of low grade biodiesel and paraffin oil. The paraffin oil is put into the beaker while the low grade biodiesel is put into the two neck round bottomed flask.

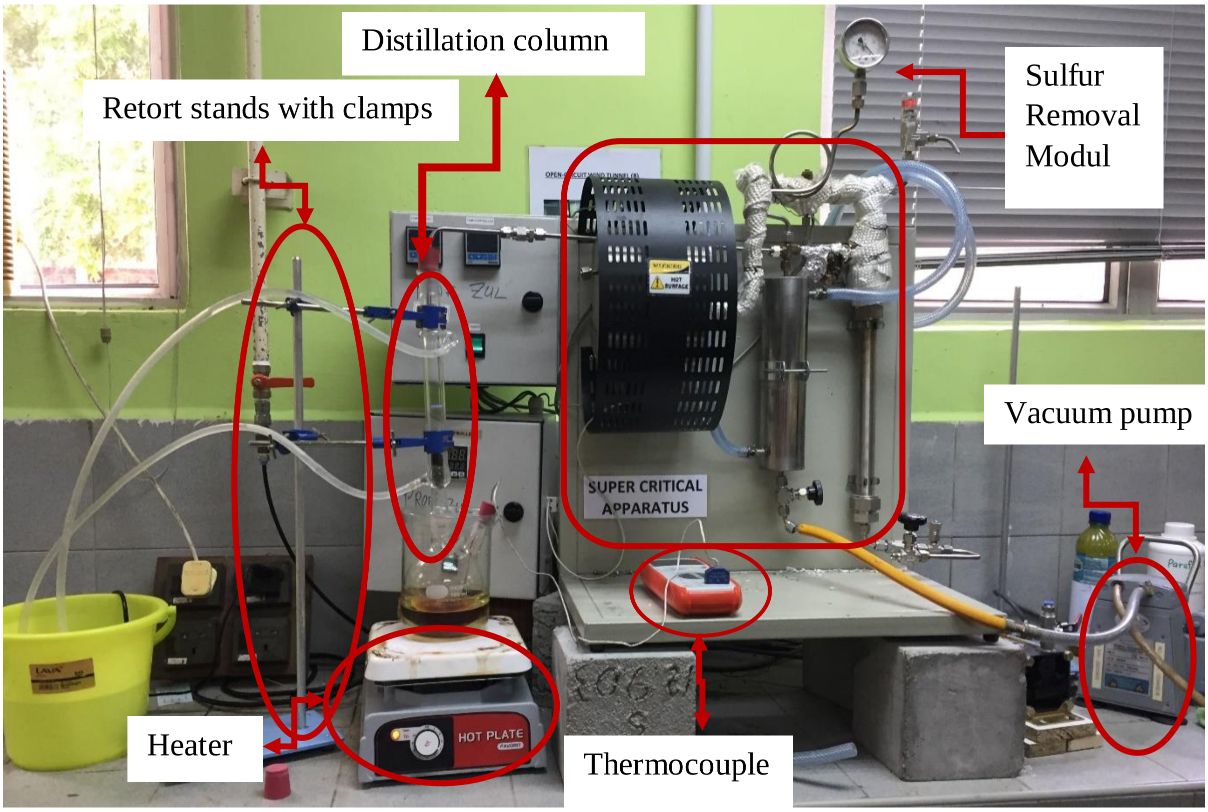

Figure 3 : The setup of the distillation equipment.

3.3 Process

There are two basic processes that involve in this experiment which are filtering and distillation process. The filtering process is the process to remove the impurities and the solid particle in the crude biodiesel while distillation process is the true process of sulfur remover.

3.3.1 Filtering Process

Filter the low grade biodiesel using a filter paper with a pore size of 50 microns thus, the solid particles and cellulosic biomass (Ma et al., 2016) were removed. The product of the filtration process is the mixture of liquid oil and water. Then separate the water in the mixture via gravitational settling (Ma et al., 2016) and collect only the oil at the upper part. The scum oil contained metal and non metal impurities, such as Ca, Fe, Al, Mg, Zn, N, P, and etc. (Bi et al., 2015).

3.3.2 Distillation Process

Transfer 100 ml of filtered high sulfur biodiesel to a customized Sulfur Removal Modul. Then the biodiesel in the two necks round bottom flask is heated until the boiling point is reached which is about 228°C to 240°C for each low grade biodiesel. The temperature is determined by using the thermocouple that is put in the biodiesel and the thermocouple is connected to the multimeter for the reading. The vacuum pump is turned on when the temperature is about 200°C and should be maintained at pressure between 20 to 40 cmHg. At the beginning of the experiment, the point of focus was to heat the biodiesel only, then at a temperature of 200°C, the suction is needed as the water and other substances must be taken out from the biodiesel to get the product with low sulfur content. The final product will be collected and then being tested to quantify the sulfur content and the calorific value.

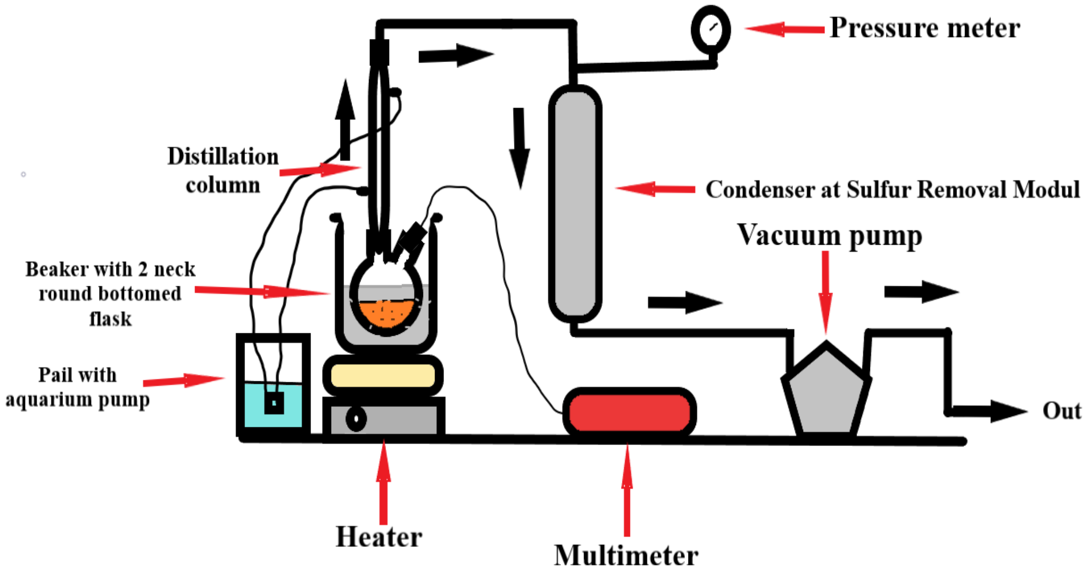

Figure 4 : Distillation process diagram.

Based on the process diagram shown is Figure 4, the arrow in black color is the pathway of the distillation process. The process starts from the heating of the biodiesel, distillation process in the distillation column, condensation process in the condenser of Sulfur Removal Modul, and lastly, suck out by a vacuum pump to the sink.

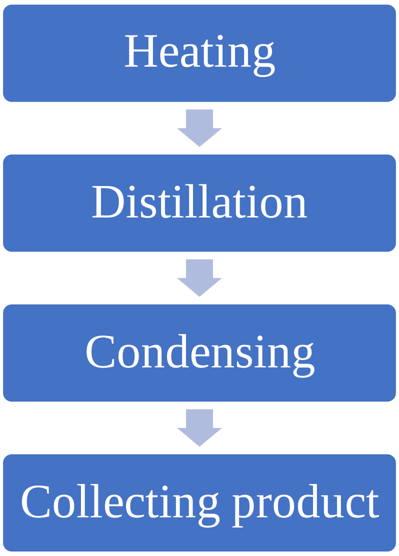

Figure 5 : Distillation process flow chart.

3.4 Testing

There are two tests that are made for this experiment which are Elemental Analyzer to determine the sulfur content and Bomb Calorimeter to determine the calorific value. The samples of 75 ml are prepared with a pair of before and after the process and put in clear containers to make ease of observing the changes.

Figure 6 : The samples of product in clear containers.

3.4.1 Elemental Analyzer

The samples of products from the experiment will be analyzed by Elemental Analyzer model PE 2400 Series II CHNS/O machine at School of Chemical Engineering, USM. This machine is used to analyze the element of Carbon, Hydrogen, Nitrogen, Sulfur, and Oxygen in a powder or liquid form. After settling down all the documents for this testing, the samples are given to the in-charge technician to be tested. The value of sulfur available in weight percentage.

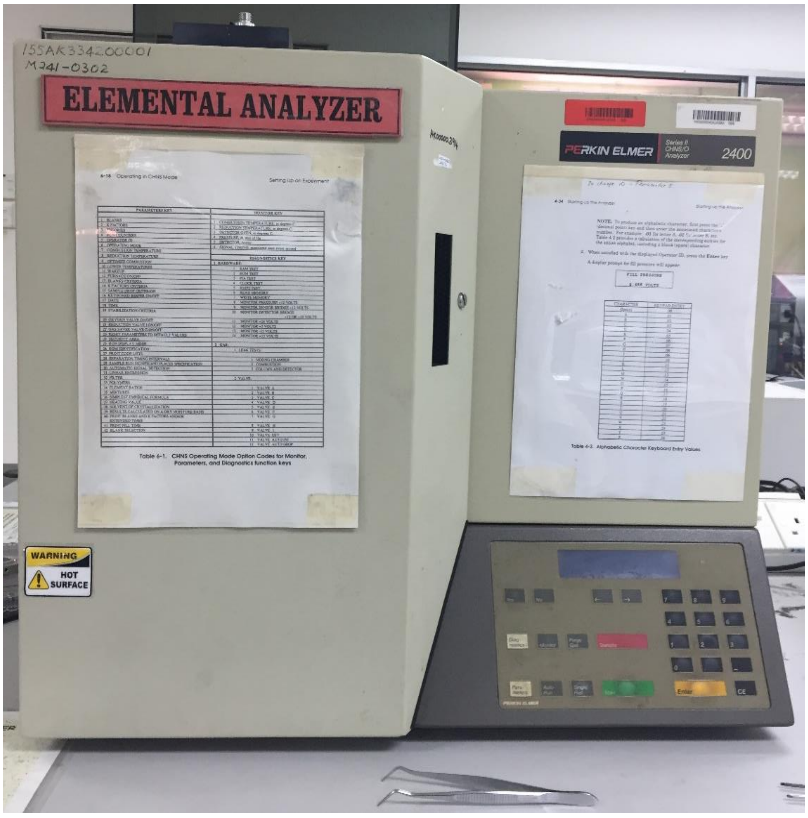

Figure 7 : Elemental Analyzer machine at School of Chemical Engineering, USM.

3.4.2 Bombcalorimeter

The samples of products are also being tested using the Bombcalorimeter in Heat Transfer Laboratory at School of Mechanical Engineering,USM to compare the calorific value in the treated biodiesel and the untreated biodiesel. Important equipment that involved in this test are Bombcalorimeter and its components, two Beckmann's thermometers, stop watch, syringe, 10 cm of nichrome wire, oxygen tank, rice paper, and digital weighing scale.

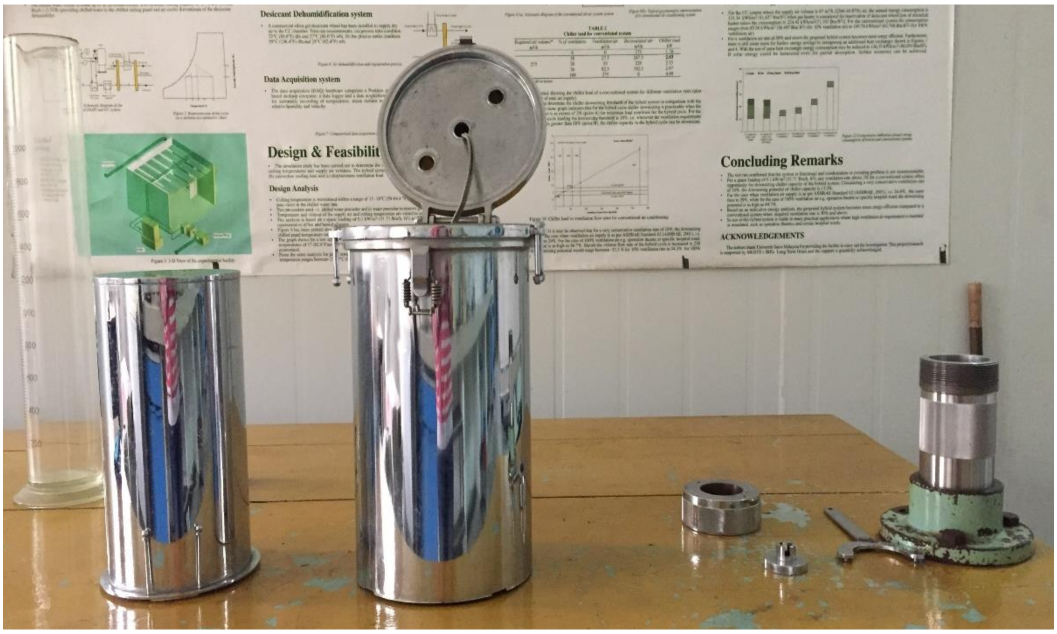

Figure 8 : Bombcalorimeter's components.

3.4.2.1 Preparation

Before starting the testing, the equipment must be prepared first. The distilled water is heated to a temperature between 24 and 27°C. Using a graduated cylinder, 2100ml of water is measured and filled into the calorimeter bucket. Then, the calorimeter bucket is placed such that the indentations on the bottom of the calorimeter bucket align with the bottom of the calorimeter. The bomb head is placed on the bomb head stand while the bomb cylinder is placed in the clamp that is affixed to the table. The clean crucible is placed on the digital weighing scale and the tare button is pushed to ensure the value of the scale is zero. Then, by using the syringe the biodiesel sample is sucked and put into the crucible. The weight of the biodiesel sample is measured. The mass must be in between 0.5-0.7 g. The crucible is then put on the bomb head. Next, mass of rice paper also measured and tied with the 10cm nichrome wire. The nichrome wire with the rice paper are attached to the bomb head through the eyelet holes. The rice paper must be submerged in the biodiesel sample. The bomb head is carefully removed from the stand and then placed in the cylinder. The screw cap is put on the cylinder and being tightened. Oxygen gas is filled in the bomb cylinder. The bomb cylinder is inserted into the calorimeter bucket. The electrodes are also inserted into the terminals on the bomb head. The calorimeter bucket is placed in the Bombcalorimeter jacket. The Beckmann's thermometers are put in its place and the initial temperature is recorded. The drive belt is installed on the motor and stirrer propeller.

Figure 9 : Bomb head with crucible on the stand.

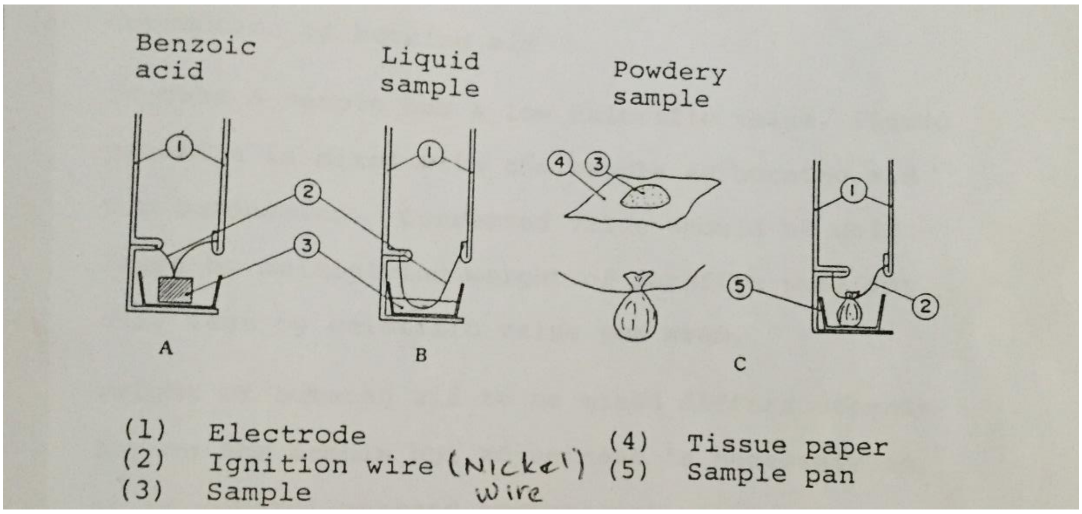

Figure 10 : Sample setting on the crucible based on (Abdul Latif B. Hamzah, n.d.)

3.4.2.2 Combustion

To start the testing, the machine must be switched on. The Bombcalorimeter is allowed to run for five minutes and then the ignition button which is red in color is pushed thus, the combustion occurred. The temperature on the Beckman thermometer in the bomb cylinder is recorded every 30 seconds. After 10 minutes, the temperature is recorded every 1 minute until the reading is the same in three times.

Figure 11 : Bombcalorimeter jacket. The red button is the ignition button.

3.4.2.3 Final Procedure

The stirrer is stopped and the drive belt is uninstalled from the motor and the stirrer propeller. The Beckmann's thermometer is removed from the Bombcalorimeter. The electrodes also been removed. The bomb cylinder is taken out and put on the clamp and the valve knob is opened slowly to remove the residual oxygen gas. The screw cap is loosened and the bomb head is removed. The bomb head is placed on the stand and the remaining nichrome wire is taken out. The length of unburned nichrome wire is measured. The inside surface of the cylinder and the crucible is cleaned. The testing is repeated for another sample of biodiesel.

3.4.2.4 Calculation

Firstly, calculate the value of correct temperature by formula,

$$T_{corr} = \text{Max Temp} - \text{Initial Temp} \ (^\circ C)$$

where the highest temperature minus with the initial temperature. Next, to find the Higher Calorific Value (HCV) of the substance,

HCV = [(Vol Water + 604) x (Tcorr) (4.19)] - [(mass of rice paper x 16190) + (Length of Burnt Wire x 2.3 x 4.19)] / Sample mass

this formula is used where the volume of water, mass of rice paper, length of burnt nichrome wire and sample mass is defined first. The result is tabulated.

CHAPTER FOUR

4 Result and discussion

The experiment and testing result will be discussed briefly in this part. The result will be included with the picture to be observed, tabulated data and graph.

4.1 Distillation product

Distillation products for all samples are put in a clear container to make ease of observing the difference between before and after treatment. The containers are labelled with the name of the sample and the cap of the container will differentiate the sample of biodiesel before and after the treatment. White cap indicates the samples of biodiesel before treatment, while black cap indicates the samples of products after distillation. Observation of the products of distillation made by observing its color and its viscosity.

Figure 12 : Samples of biodiesel before and after treatment.

4.1.1 Crude Palm Oil

The distillation product of crude palm oil is put side by side with the crude palm oil before treatment to be observed as in Figure 13.

Figure 13 : Crude palm oil before and after treatment.

As can be seen in the figure, the color of the crude palm oil is more to orange in color and a bit cloudy while the treated crude palm oil is brown in color and clearer compared to the crude palm oil and the viscosity of the crude palm oil is higher than the treated one. Higher temperatures will lower the viscosity of the crude palm oil thus proved the study by (Keshvadi et al, 2011) and (Tangsathitkulchai et al., 2004) which said the crude palm oil exist as solid fat particles at a lower temperature. When the crude palm oil is heated, the solid particles will disperse and the clearer with low viscosity of palm oil is produced.