SUPERVISOR DECLARATION

" I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of
Bachelor of Mechanical Engineering (Thermal-Fluids with Honours)"

Singnature: .....
Supervisor: MDM. MAHANUM BINTI MOHD ZAMBERI
Date: JUNE 2013

TRIBOLOGICAL PROPERTIES OF WASTE VEGETABLE OIL BIODIESEL USING-ALKALINE-BASED POTASSIUM HYDROXIDE (KOH) CATALYST

HAZALIFAH BINTI ZAINAL ABIDIN

This report is submitted in partial fulfilment of requirements
in order to be awarded with
Bachelor of Mechanical Engineering (Thermal-Fluids with Honours)

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

JUNE 2013

DECLARATION

"I hereby declare that the work in this report is my own expect for summaries and quotations which have been duly acknowledged."

Signature: .....
Author: HAZALIFAH BINTI ZAINAL ABIDIN
Date: JUNE 2013

Specially dedicated to my beloved family especially my parent
Zainal Abidin bin Talib and Hasnah binti Mansor
and those people who have guide and inspired me throughout my Final Year Project.

ACKNOWLEDGEMENT

In the Name of Allah, Most Gracious, Most Merciful. Thanks God with His blessing, I manage to complete the Projek Sarjana Muda I. This is a special tribute to the Universiti Teknikal Malaysia Melaka for giving me the opportunity to gain as much valuable knowledge throughout the study here.

My sincere appreciation also goes to my supervisor, Mrs. Mahanum binti Mohd Zamberi for her willingness to share all her impressive knowledge in the field of biodiesel with me and her continued valuable guidance and advice throughout the whole period in the completion of this project. All her wise advice, guidance and knowledge provided will be apply in the future.

Not forgetting a special thanks to my first panelist, Mr. Imran Syakir for his cooperation to accomplish the Projek Sarjana Muda. All positive criticism helped me to improve my weaknesses. Thank you so much also extended to all laboratory technicians that involved in the project.

A special appreciation goes to my loving parents for their endless support and encouragement to me to complete this project successfully. Last but not least, to all my family members was give words a lot of enthusiasm to complete this Projek Sarjana Muda. Thanks a lot. Finally, my special dedication to my colleagues who are involved directly or indirectly in order to complete the project.

ABSTRAK

Biodiesel merupakan tenaga boleh diperbaharui yang mempunyai ciri bahan bakar yang hampir sama dengan minyak diesel konvensional. Penghasilan biodiesel adalah melalui proses transesterifikasi yang melibatkan tindakbalas kimia untuk memisahkan glyserol daripada minyak terpakai. Biodiesel ini telah menjalani tujuh jenis ujian sifat bahan api iaitu titik kilat (ASTM D93), kelikatan kinematik (ASTM D445), kandungan air (EN ISO 1293) dan sebagainya. Laporan ini lebih menjurus kepada kajian terhadap sifat-sifat tribologi terhadap kumpulan biodiesel di mana terdapat empat jenis kumpulan biodiesel yang dikaji iaitu B100, B5, B10, dan B20. Terdapat tiga sifat tribologi yang telah dikaji iaitu pekali geseran, parameter suhu kilat dan diameter kesan haus. Eksperimen ini telah dijalankan dengan menggunakan mesin ujian empat bola untuk menentukan ciri-ciri tribologi biodiesel dan mesin mikroskopi penyongsang pula digunakan untuk mendapatkan purata diameter kesan haus. Peningkatan kepekatan biodiesel bahan api diesel telah membawa kepada penurunan nilai pekali geseran walaupun pada beban yang lebih tinggi. Nilai diameter kesan haus merosot secara perlahan-lahan pada 40 dan 15 kgF beban apabila kepekatan biodiesel berkurang. B100 menunjukkan pelincir yang paling baik dari segi pekali geseran, namun ia mempunyai nilai diameter kesan haus yang besar. B20 menunjukkan pelinciran yang terbaik diantara sample biodiesel campuran yang lain kerana mempunyai nilai pekali geseran dan diameter kesan haus yang rendah, dan mempunyai nilai parameter suhu kilat yang tinggi untuk kedua-dua jenis beban.

ABSTRACT

Biodiesel is a renewable energy that has the fuel properties almost similar to conventional diesel fuel. Biodiesel production through transesterification process, involved a chemical reaction to separate the glycerol from the waste vegetable oil. Biodiesel had been undergo seven types of fuel testing properties which are flash point, (ASTM D93), kinematic viscosity (ASTM D445), water content (EN ISO 1293) and the others. This report was focused on the tribological properties of the biodiesel blends where there are four different group of studies, B100, B5, B10 and B20. There are three types of tribological properties that was considered which are coefficient of friction (COF), flash temperature parameter (FTP) and wear scar diameter (WSD). This experiment will be carried out using four ball tester (FBT) to determine the tribological properties of biodiesel. Meanwhile, Inverter Microscope was used to define the average wear scar diameter. The increment of biodiesel concentration to the diesel fuel leads to the decrement of *COF* value even at higher load. The *WSD* slowly decline at 40 kgF and 15 kgF of load, as the reduction of the biodiesel concentration. The B100 shows the excellent lubricant in term of *COF*, nevertheless it have the greater value of the *WSD*. B20 observed to be a good lubricity compared with the biodiesel blends due to its low value of *COF* and *WSD*, as well as high in *FTP* under both type of loads.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND SYMBOLS

ASTM	=	American Society for Testing and Materials
COF	=	Coefficient Of Friction
CO	=	Carbon Monoxide
CO_2	=	Carbon Dioxide
B100	=	100% of Biodiesel Blend, 0% Petrol Diesel
B5	=	5% of Biodiesel Blend, 95% Petrol Diesel
B10	=	10% of Biodiesel Blend, 90% Petrol Diesel
B20	=	20% of Biodiesel Blend, 80% Petrol Diesel
D	=	Mean Wear Scar Diameter
FBT	=	Four Ball Tested
FFA	=	Free Fatty Acid
FTP	=	Flash Temperature Parameter
KOH	=	Potassium Hydroxide
NaOH	=	Sodium Hydroxide
$NaOCH_3$	=	Sodium Methoxide
POME	=	Palm Oil Methyl Ester
r	=	Radius
RBD	=	Refined, Bleached and Deodorized
S	=	Sulfur
SAE	=	Society of Automotive Engineers
SEM	=	Scanning Electrode Microscopy
TAN	=	Tan Acid Number
VI	=	Viscosity Index
W	=	Load
WSD	=	Wear Scar Diameter
WVO	=	Waste Vegetable Oil

°C	=	Degree Celcius
μ	=	Coefficient of Friction
T	=	Frictional Torque
ρ	=	Density

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Currently, the growing of renewable energy has shown a drastic increased in our country for the past ten years due to the energy consumption and variable demands. Societies or industry are encouraged to find the alternative of renewable energy to reduce the dependency on petroleum based fuel demand. The utilization of renewable energy will help in alleviating the increasing rate of pollution in the country. Biomass, hydro, solar panel, wind turbine, and tidal water system are some of the typical types of renewable energy.

Biodiesel is one of the alternatives fuels where it can be produced from waste cooking oil, animal fat, soybean, rapeseed, cottonseed and others. Tandon, A. et al., (2011), in their studies found that German is the biggest country in production of biodiesel. Biodiesel was first developed by Rudolph Diesel in 1900, where he introduced the concept of using biofuels in the engine combustion system. At that time, the peanut oil has been used as fuel in diesel engines but a few years later it is no longer being used after the findings of fossil fuel that more cheap. Early 21st century, biodiesel was developed back and the research was started when people started realized the depleting resources of fossil fuel and its negative impact to the environment. Nevertheless, high viscosity and low volatility are the greatest obstacles that need to resolve before biodiesel can be considered to replace diesel fuel. Therefore, more research has been carried out to enhance the quality and at the same time reduce the viscosity of biodiesel. The studies were conducted by varying

the types of feedstock, process and standardized the minimum biodiesel properties to enable the use of biodiesel in the engine system.

Based on the research by Kywe, T. T. & Oo, M. M., (2009), the fossil fuel is a major contributor to the global air pollution problem because it is produced unwanted emission gas such as carbon dioxide (CO_2), carbon monoxide (CO), sulfur (S) and others which can directly jeopardizes the environment. The researchers were still struggling to search for the sources of renewable energy due to the fluctuating of the fuel price and the depletion of world petroleum reserve. They also aims to select the best alternative energy resources that can replace the dependency on fossil fuel without contribute negative impact to the environment. Biodiesel was found to be the best option to replace the dependence on petroleum based fuel in future, because its fuel properties similar to petroleum based fuel, in which biodiesel can be produced either from vegetable oils or animal fats. However, vegetable oil is preferred to be used in biodiesel production due the huge resources and lower cost of production compared to the animal fat feedstock.

In this project, waste vegetable oil (WVO) has been used as a raw material with methanol as alcohol. It is produced through a chemical reaction comprising of long chain alkyl esters. Biodiesel was produced by transesterification process, of a biodiesel production process using a mixture of alcohol and waste oil with assisted catalyst. Temperature and pressure are two main parameters need to be considered in the biodiesel production. Methanol and ethanol are widely used as an alcohol, whilst sodium hydroxide (NaOH), potassium hydroxide (KOH) and sodium methoxide ($NaOCH_3$) are the most popular catalyst being used.

Research on tribological properties of biodiesel is essential in order to determine the performance levels of the biodiesel and the effects of chemical. One of the major concerns when using biodiesel is the higher friction level produced and low rate of lubrication that may contributes to the failure in the engine system. At present, the Four Ball Tested (FBT) is the most widely used in measured the lubricant quality of the sample. Other than that, this machine also able to determine the wear and tear of the sample tested by specified time and temperature.

Biodiesel blend, B50 has the higher rate of wear compared to B5 due to the higher metallic element. According to Wain, K. S. et al., (2005), the contents of oxygen, O_2, in the biodiesel also will be affected to the friction and wear. ASTM 4172 and ASTM 5183 are the standards required for the tribology test; ASTM 4172 for the effect of wear and ASTM 5183 standard for the effect of friction. Others parameters that also can be obtained by using this test were the coefficient of friction (COF), wear scar diameter (WSD) and flash temperature and parameter (FTP).

Furthermore, the *WSD* can be analyse closely by using the Inverter Microscope. The inverter microscope is a device that used to produce a magnified image from the smallest object by using lens, where it different compared to the conventional microscope consequence to the capability of Inverter Microscope in analyse the overall surface intensively and clearly. In addition, the Inverter Microscope also is provided with video cameras, fluorescence illumination, confocal scanning and the others. The most advantage of the Inverter Microscope is able to obtain the image of *WSD* and produced the data required directly.

1.2 OBJECTIVE

The overall aim of this project is to find the best sample of biodiesel blend in term of tribological properties. There are three specific objectives on this study:

i. To identify main dependencies of tribological properties of alkaline based on catalyst (KOH) by using Four Ball Test (*FBT*) and Inverter Microscope.
ii. To investigate the tribological characteristic to the biodiesel group of B5, B10, B20 and B100.
iii. To analyze the characteristic performance the biodiesel group of B5, B10, B20 and B100.

1.3 SCOPE

In this project, there scopes are outlined as follows:

i. To study the tribological properties of biodiesel.
ii. To perform an experimental research of tribological biodiesel fuel using wear and friction test machine (*FBT*).
iii. To analyze the captured database on biodiesel pure and several types of biodiesel blends from waste vegetable oil.
iv. To observe and analyze the *WSD* clearly by using Inverter Microscope.

1.4 PROBLEM STATEMENT

The problem statement is a problem that should be studied in the project. This is essential to explain in detail about the project problems. Among the problem statement in this project is shown below:

- The excellent of tribology properties is crucial to ensure the engine system being able to operate at the optimum condition. The unacceptable value of coefficient of friction, wear scar diameter, and flash temperature of biodiesel fuel leads to the losses of engine life time, reduction of reliability, power losses and destruction to the engine system directly. Previously, the lubricant selection was made based on the experience and knowledge that possessed by a person. The evaluation without using specified standard is not accurate and varies with different people.

- In this study, the characteristic of biodiesel in tribology aspect would be identified based on ASTM standard in order to evade the engine breakdown. The research aims to recognize the best type of biodiesel blends that would give the superior performance to the engine system by using four-ball testing machine.

CHAPTER 2

LITERATURE REVIEW

2.1 BIODIESEL

Biodiesel is one of the renewable resources that have the potential to replace the dependence on diesel fuel in the future. Biodiesel can be produced using vegetable oils or animal fats whether the feedstock is virgin or that have been used. Commercially, the raw material source that used in the biodiesel production is commonly known as corn, cottonseed, sunflowers seeds, algae, rapeseed, palm oil and others. Biodiesel can be used by any vehicle that uses diesel as fuel. Usually, the raw materials used in the production of biodiesel based on the most abundant resources available in the country. For example, according to the article by Samy Sadaka found that the soybeans are one of the raw materials that used extensively in the process of biodiesel production in Arkansas due to the easy access of the resource.

2.2 BIODIESEL PRODUCTION

A study done by Zamberi, M. M. et al., (2010), stated that the biodiesel production process consists of four main processes known as preprocessing, transesterification, washing and drying. It has strongly supported by Dennis, Y. C. L. et al., (2010), where, the production of biodiesel involves all the process except drying process. Figure 2.1 shows the biodiesel production model.

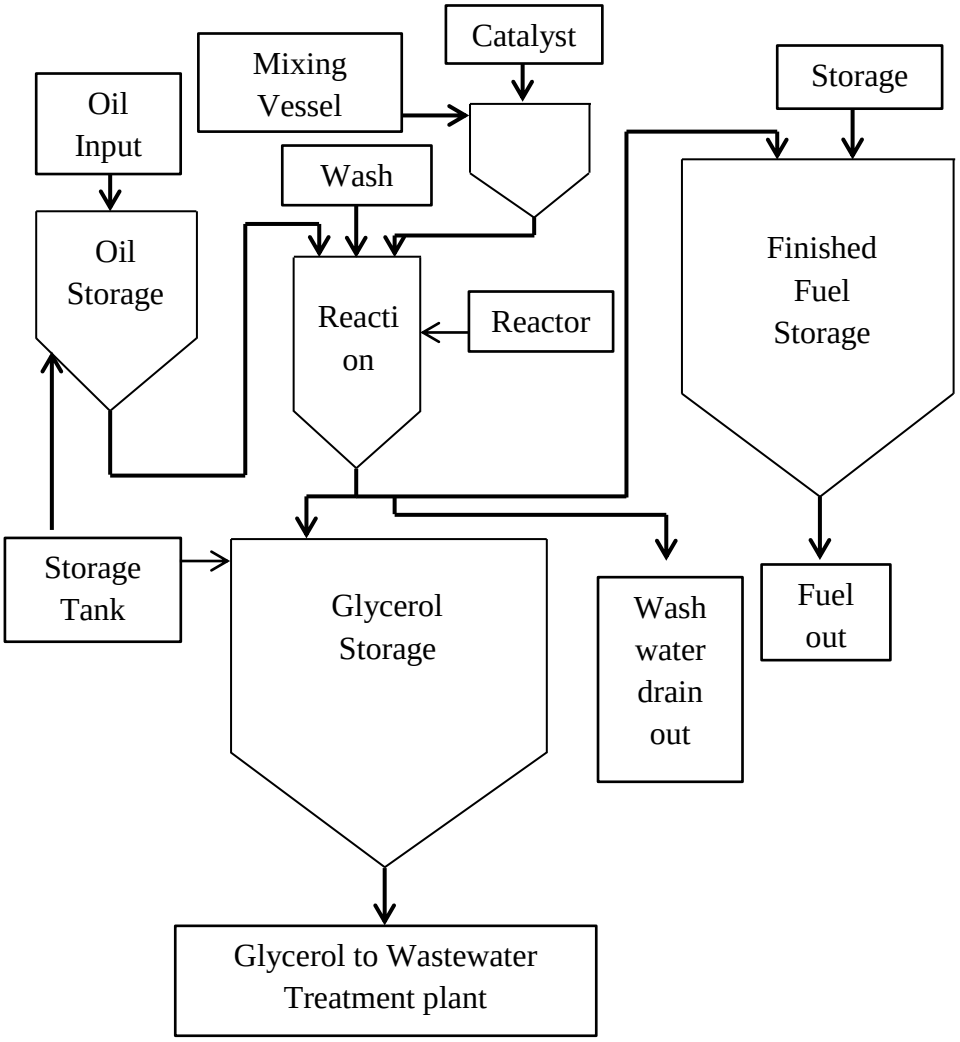

Figure 2.1: The biodiesel production model

2.2.1 Pre-processing

Pre-processing includes titration and pretreatment process. The purpose of titration process is to identify the percentage of free fatty acid (FFA) in the oil feedstock. If the content of FFA below than 2.5%, oil feedstock will be proceed to the next process which transesterification process. Conversely, feedstock oil needs to undergo the pretreatment process when the percentages of FFA are higher than 2.5%. In the pretreatment process, the acid will be mixed in a certain amount with oil to eliminate the percentage of FFA. Figure 2.2 shows the sequence of the simplified process flow chart of alkaline-catalyst in pre-processing biodiesel production.

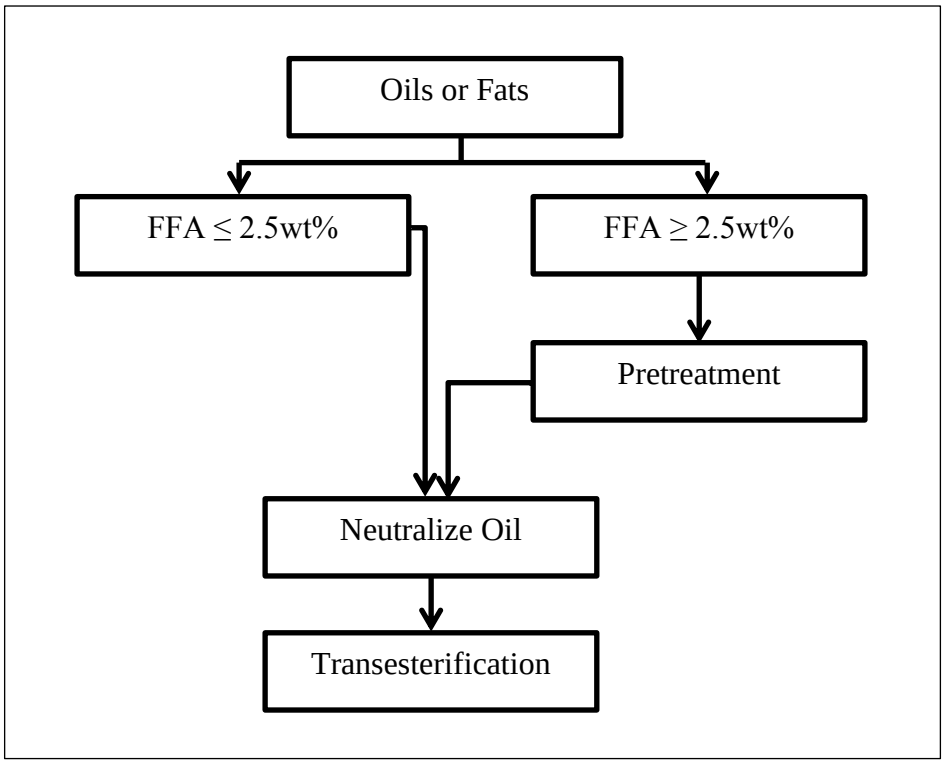

Figure 2.2: Simplified process flow chart of alkaline-catalyst in pre-processing biodiesel production

2.2.2 Transesterification

Referring to the Martin, P. (2007), the transesterification is a chemical process using alcohol and catalysts to assist in biodiesel production. WVO known as triglyceride will react with alcohol and catalysts to generate the separation of glycerol and ester. The products from this reaction produce two region of oil; which glycerol is slightly darker and bright oil is biodiesel. In this research, six variables were chosen to identify the best biodiesel fuel. The variables are molar ratios of glycerides to alcohol, type of catalysts, reaction temperature, reaction time, water content and free fatty acid content of feedstock oils. In this project, there are only four variables that will be focus; molar ratios of glycerides to alcohol, type of catalysts, reaction temperature and reaction time. Figure 2.3 shows the transesterification process in order to produce a complete biodiesel.

due to the ability to avoid the soap formation. The homogeneous catalysts are sodium hydroxide (NaOH), potassium hydroxide (KOH) and sodium methoxide ($NaOCH_3$). From the previous research by Dennis, Y. C. L. et al., (2010), the types of catalysts commonly used are KOH and NaOH. Meanwhile Zamberi, M. M. et al., (2010), revealed that the KOH is the best catalyst due to the higher value of power and torque produce in diesel engine.

2.2.2.3 Reaction Temperature

The reaction temperature is another factor that can contributes stains in the biodiesel production. Mathiyazhagan, M. & Ganapathi, A. (2011) in their article stated that the reaction temperature will affect the reaction rate and viscosity. By increasing the reaction temperature, the reaction rate between FFA and alcohol will be increase and the rate of viscosity will be decrease.

2.2.2.4 Reaction Time

The percentage of biodiesel yield depends closely on the reaction time, where the percentage of yield will slightly increase with reaction time. Research done by the Alamu, O.J. et al., (2007), found that the reaction time under 90 minutes is the optimum time to gain the higher percentage of yield. The increment of the reaction time greatly gives advantage to biodiesel yield.

2.2.3 Washing

The washing process is divided into two categories which are water washing and dry washing. Primary material that can be used in water washing process is distilled warm water and softened water. Water washing is an effective process to remove all the contaminants. The residual of sodium salts and soap also can be