"I / we* admit that have read
this work and in my/our* opinion this work
was sufficient from the aspect of scope and quality for the award of the
Bachelor's Degree of Mechanical Engineering (Thermal-Fluid)"

Signature : .....

Supervisor Name : Puan Mahanum Binti Mohd Zamberi

Date : .....

Signature : .....

2nd Supervisor Name : Dr. Yusmady Bin Mohamed Arifin

Date : .....

# DIESEL ENGINE PERFORMANCES OF ALKALINE-CATALYST UFO BIODIESEL

YEW WAI KEAI

This report is submitted as partial requirement for the completion of the Bachelor of Mechanical Engineering (Thermal-Fluid) Degree Programme

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

MAY 2010

"I declared that this report is the result of my own work except for the summary and text that I have acknowledged its sources"

Signature : .....

Author : YEW WAI KEAI

Date : .....

"To my beloved family and friends
who give encouragement throughout my whole report"

## ACKNOWLEDGEMENT

I could not complete this study without any assistance of many people. Most importantly, my deepest thanks go to my PSM supervisor, Madam Mahanum Binti Mohd Zamberi for giving me this precious opportunity to do this study. Special thanks to her for her unfailing assistance, guidance and encouragement.

Special thanks to Mr. Mohd Zulkifli for his time, experience and guidance. He helped me a lot in this study. Special thanks to my friends and uncle who is willing to teach and share the information with me. My uncle provided me a lot of useful information.

I extend great appreciations and thanks to all of them for their time, experience, wisdom and above all their kindness and understanding. Without them, I could not complete this study.

Thank you so much!

## ABSTRACT

The methyl ester of UFO, known as biodiesel, is getting increasing interest as an alternative fuel for compression ignition engines due to its lower cost, largest producer and reduces the disposal problem. In this study, three biodiesel fuels which produce by several alkaline-base catalysts with methanol via transesterification were then tested in a four cylinder Mitsubishi Pajero 2.5L Intercooler Turbo Diesel Engine. The engine performances were recorded under 65% loads and at six different speeds. This study presents the torque, brake power and brake specific fuel consumption of the biodiesel fuels compare with the virgin oil (VO) biodiesel fuel and diesel fuel. All of the biodiesel fuels exhibited the nearly similar performance characteristic at the speed from 1000 rpm to 3000 rpm. At the speed 3500 rpm, the performance different become more significant. For obtain the higher power and torque, the potassium hydroxide (KOH) is the best catalyst use to produce UFO biodiesel. However, to obtain the economy fuel (based on the brake specific fuel consumption) and lower engine temperature the sodium hydroxide (NaOH) as catalyst is advised.

# ABSTRAK

Metil ester melalui minyak masak terpakai (UFO) yang juga dikenali sebagai biodiesel, semakin penting dan dikenali sebagai bahan api gantian untuk enjin cucuhan mampatan kerana kosnya yang rendah, penghasilan yang tinggi dan dapat mengurangkan masalah sisa pembuangan. Dalam kajian ini, tiga jenis biodiesel yang dihasilkan dengan mengguna pemangkin alkali yang berbeza dengan metanol melalui transesterifikasi diuji dalam enjin diesel empat lejang model Mitsubishi Pajero 2.5L Intercooler Turbo. Pretasi enjin dicatatkan dalam 65% beban dan pada enam kelajuan yang belainan. Tujuan utama kajian ini dijalankan adalah untuk mengenalpasti tork, kuasa brek dan penggunaan bahanapi spesifik brek untuk biodiesel UFO berbanding dengan minyak diesel dan minyak asli (VO) biodiesel. Semua biodiesel yang digunakan menunjukkan sifat kecekapan yang hampir sama pada kelajuan dari 1000 rpm hingga 3000 rpm. Dalam kelajuan 3500 rpm, pretasi yang berbeza mejadi lebih jelas. Untuk mendapat kuasa dan tork yang tinggi, kalium hidroksida (KOH) ialah pemangkin terbaik untuk menghasilkan UFO biodiesel. Tetapi, untuk mendapat bahan pembakar yang lebih jimat (berbantu daripada penggunaan bahanapi spesifik brek) and suhu enjin yang rendah natrium hidroksida (NaOH) adalah dicadangkan.

# TABLE OF CONTENT

# LIST OF TABLE

# LIST OF FIGURES

# LIST OF SYMBOLS

| | | |
|---|---|---|
| r | = | Bore radius, m |
| S | = | Length of Stroke, m |
| $N_c$ | = | Number of cylinders |
| VE | = | Volumetric Efficiency |
| MEP | = | Mean effective pressure, Pa |
| $W_{net}$ | = | Net work, J |
| $V_{max}$ | = | Maximum volume, $m^3$ |
| $V_{min}$ | = | Minimum volume, $m^3$ |
| iMEP | = | Mean indicated pressure, Pa |
| A | = | Area of piston, $m^2$ |
| L | = | Stroke of piston, m |
| $N_s$ | = | Number of power strokes per cylinder per second |
| ip | = | Indicated power, W |
| bp | = | Brake power, W |
| T | = | Torque , Nm |
| N | = | Speed , rpm |
| $F_d$ | = | Net dynamometer load |
| R | = | Torque arm length, m |
| isfc | = | Indicated specific fuel consumption, g/kWh |
| $\dot{m}_f$ | = | Fuel mass flow rate, kg/h |
| bsfc | = | Break specific fuel consumption, g/kWh |
| $\eta_i$ | = | Indicated thermal efficiency |
| $\eta_b$ | = | Brake thermal efficiency |

# LIST OF APPENDICES

# CHAPTER I

## INTRODUCTION

Diesel fuel is a fuel that refine from the petroleum fuel which is naturally found in the Earth. It cannot be renewed and will be run out in the future. Therefore, alternative method to replace the diesel fuel has been studied. Numerous methods have been researched and one of them is biodiesel production. The biodiesel is the most suitable because there is no big alter in the diesel engines and it tends to provide nearly similar power as diesel fuel.

Biodiesel is a fuel made from vegetable oils and alcohols utilizing a chemical process called transesterification. This process required presence of catalyst with an alcohol to give the corresponding alkyl ester of fatty acid (FA) found in parent vegetable oil or animal fat. Biodiesel can be produced from variety feedstock such as soy bean, palm oil, rapeseed oil and so on. However, biodiesel is currently not economically feasible due to high manufacture and materials cost. Thus, the tax credits are applied on it.

Due to this reason, several studied have been carried out to optimize the process by using the low price feedstock such as castor oil and used frying oil (UFO). Using UFO to produce biodiesel is getting increasing interest as an alternative fuel for compression ignition engines owing to its cost is lower, largest producer and can reduce the disposal problem. Thus, many researchers studied on its performance of different engines and increase the yield of production. Besides that, certain researchers also try to optimize its performance by using different alcohol.

After the fuel has been produced, the diesel engine test is required to evaluate the performance of the biodiesel fuel. As the engine's performance test will show the different performance due to different fuel. Hence, an engine test will be carried out after the biodiesel has been produced due to test its applicability and the interest by consumer. Normally, the performance of fuel will be validated based on the maximum torque, maximum power and fuel consumption obtained in the experiment.

In this study, three of the pure biodiesel (B100) will be produce from UFO and methanol via transesterification with different alkaline based catalyst. These products will be tested in the diesel engine; the better catalysts will be decided based on the engine performance. Moreover, these biodiesel fuels also will be compared with the biodiesel which produced from virgin oil (VO) and petrol diesel to authorize its performance. This study will be carried out in the 2.5L Turbo Diesel Mitsubishi Pajero at FKM automotive laboratory in Universiti Tun Hussein Onn Malaysia.

## 1.1 Objective

This study is aimed to study the performance of diesel engine through different alkaline catalyst UFO biodiesel fuels. They will be compared with the current diesel fuel and the VO biodiesel fuel. The following are the objectives to be reached via the study:-

1. To study the common diesel engine performance characteristics, dynamometer models, measurement type and common critical parameters during engine diagnose.

2. To study the safety experimental procedures of diesel engine diagnose using existing dynamometer.

3. To measure the engine performance of alkaline-catalyst UFO biodiesel, VO biodiesel and current diesel fuel.

## 1.2 Scope

This study is focus on the general performance characteristic which using the existing unaltered diesel engine and dynamometer that available in the automotive laboratory. The specifications on the apparatus and procedures have to be taken as considerate. The scopes of this research are:-

1. To summarize the common diesel engine performance characteristics, measurements and dynamometer type.

2. To design the worksheet of expected data and experimental procedure, consist of predetermine parameters setup, dynamometer limits and constrain, predefine load and rpm by considering safety work procedure.

3. To analyze the captured data base on several type of alkaline-catalyst UFO biodiesel and compare it to VO biodiesel and diesel fuel. This study will determine the best catalyst used during biodiesel production.

## 1.3 Problem Statement

This study can be carried out by using the different equipments to run the test and studying the different performance characteristics. Numerous methods and different parameter can be used in engine testing to study the results. Besides that, biodiesel might acquire from raw material and the common references need to be considered. Below are the problem statements for this study:-

1. There are numerous types of engines and dynamometers can be used to test the performance characteristics. All the equipments will have the different specification based on the requirement of the research, along with the different measurement methods.

2. There are lot of different predetermine parameters have been used by the researchers to find out the relationship with the parameters. Due to this reason, the procedures and worksheet also difference.

3. Different catalysts had been used by researchers to produce the biodiesel. Commonly, the catalysts can be separated to two groups which are the acid based catalyst and alkaline based catalyst. Different catalysts will affect the fuel characteristic thus the engine performance characteristic will different too. Besides that, a references fuel need to be set as datum to compare.

# CHAPTER II

# LITERATURE REVIEW

## 2.1 Fuels

Fuel is the material that can be burned or otherwise consumed to produce heat. Fuel releases its energy either through a chemical reaction means, such as combustion, or nuclear means, such as nuclear fission or nuclear fusion. The carbon and hydrogen in fuel rapidly combine with oxygen in the air in an exothermal reaction.

### 2.1.1 Diesel Fuel

Diesel fuel is the fuel that typically produced through refining and distillation of crude oil. Crude oil is the oil found in the Earth and contains components range from methane and propane to gasoline to diesel fuel, to asphalt and other heavier components. The refining process separates the crude oil into mixtures of its constituents, based primarily on their volatility.

The diesel fuel will be cheaper compare with the gasoline because it takes less refining due to the longer carbon atoms chains than gasoline. Normally, gasoline is $C_9H_{20}$, whereas Diesel fuel is $C_{14}H_{30}$. Besides that, diesel fuel is heavier, oilier and

evaporates much slower than gasoline. The boiling point of diesel is higher than boiling point of water.

In addition, the diesel fuel has higher energy density than gasoline, which for every one gallon of diesel fuel contains 155MJ energy where for one gallon of gasoline just contains 132MJ energy. Due to the high energy density, it wide used to power up the vehicles and operations. This can observe from that 94% of freight relies on the diesel fuel.

Diesel fuel emits very small amounts of carbon monoxide, hydrocarbons and carbon dioxide, emissions that lead to global warming. On the other hand, diesel fuel will released high amounts of nitrogen compounds and particulate matter (soot) which leads to acid rain, smog and poor health conditions. Thus, certain modified and processes have done on the diesel fuel to make it more environments friendly.

Commonly, diesel fuel can be classification into number one diesel (1D), number two diesel (2D) and number four diesel (4D). Number three diesel (3D) was no longer produced (Starbuck, J. *et al* 2009). Based on the description by the Starbuck, J. *et al* and Norman *et al*, 4D is used in the lower-speed engine such as generators and railway train locomotives where the engine's speed is fairly constant. 1D and 2D are the common diesel used on road. 1D is a premium fuel used in high rpm engine requiring frequent changes of load and speed, with better winter characteristics (Cetane number about 45 to 50). 2D is used in the truck fleet due to its greater heat value per gallon and greater lubricating the engine compare with 1D (Cetane number about 40 to 45).

### 2.1.2 Biodiesel Fuel

Biodiesel is briefly defined as the monoalkyl esters of vegetable oils or animal fats through a process call transesterification (Figure 2.1). However, in the Fuel Standard Regulations 2001, biodiesel as a diesel fuel substitute obtained by esterification of oil derived from plants or animals. Biodiesel is the best candidate for

diesel fuels in diesel engines due to it burns like petroleum diesel as it involves regulated pollutants. Besides that, biodiesel probably has better efficiency than gasoline. In theoretical, biodiesel should produce the same energy as diesel fuel. Biodiesel exhibits great potential for unaltered form compression-ignition engines.

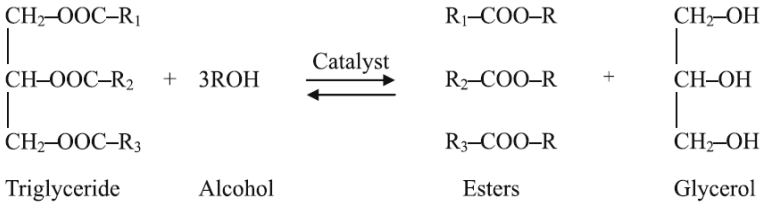


Figure 2.1: Transesterification Process

(Source: Demirbas, A. 2008)

In Table 2.1 shows the varieties feedstocks for producing biodiesel which are generally are vegetables oils (e.g. soybean, palm, peanut etc), animal fats (e.g. tallow) and waste oil (e.g. used frying oil). Besides that, biodiesel has several advantages compared with petrol diesel and fully competitive with petrol diesel in most technical aspects had been state by Knothe, G. et al (2005).

Table 2.1: Feedstocks Used for Biodiesel Manufacture

(Source: Christopher Strong *et al*)

| Vegetable Oils | Animal Fats | Other Sources |
|---|---|---|
| - Soybeans<br>- Rapeseed<br>- Canola Oil<br>- Sunflower Oil<br>- Sunflower Seed<br>- Yellow Mustard Seed | - Lard<br>- Tallow<br>- Poultry Fat | - Recycled Restaurant Cooking Oil (Yellow Grease). |