Faculty of Mechanical Engineering

AN EXPERIMENTAL INVESTIGATION OF PERFORMANCE AND GASSEOUS EXHAUST EMISSION OF A DIESEL ENGINE USING BLENDS OF A VEGETABLE OIL

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in fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering (Thermal-Fluids) with Honours

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DECLARATION

I declare that this thesis entitled "An Experimental Investigation of the performance and Gaseous Exhaust Emission of A Diesel Engine Using Blends of a Vegetable Oil" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : **MUHAMMAD SYAKIR BIN AB RAHIM**

Date : .....

SUPERVISOR'S DECLARATION

I hereby declare that I have read this project report 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.

Signature : .....

Name of Supervisor : **MD ISA BIN ALI**

Date : .....

DEDICATION

To my beloved mother and father.

ABSTRACT

Alternative fuels have received much attention due to the depletion of world petroleum reserves and increased environmental concerns. Vegetable oils can provide cleaner burning and renewable alternatives to diesel fuel. Thus, vegetable oil offers as an attractive alternative fuel to compression ignition engines. However, their inherently high viscosity as compared to petroleum based diesel is undesirable for diesel engines. This research concentrates on the study of the prospect of using vegetable oils as a replacement for diesel fuel by configuring an experiment to test the engine's performance and to determine the level of emission on three fuel blends of coconut oil such as 10%, 20% and 30% of coconut oil – diesel blends. The presented work investigates the engine performance parameters and emissions characteristics for direct injection diesel engine using coconut diesel blends without any engine modifications. Experiment has been conducted at a fixed engine speed of 2500 rpm, and then it was gradually loaded. The experiments were conducted at five loads, namely 0 bar (no load), 10 bar, 20 bar, 30 bar and 40 bar. For each load condition the engine was run for at least 4-5 minutes. Results show that the basic engine performance such as power output and fuel consumption is comparable to diesel. When fueled with diesel blends, reduction of power output and incline fuel consumption was noted and with the increased amount of coconut oil in the blends. In case of engine exhaust gas emissions, lower CO_2 and NOx, while higher CO and HC emissions have been found for blended fuels compared to diesel fuel.

ABSTRAK

Bahan api alternatif telah menerima banyak perhatian kerana pengurangan rizab petroleum dunia dan peningkatan kebimbangan alam sekitar. Minyak sayuran boleh menyediakan pembakaran yang lebih bersih dan alternatif yang boleh diperbaharui untuk bahan api diesel. Oleh itu, minyak sayur-sayuran menawarkan bahan api alternatif yang menarik kepada enjin pencucuhan mampatan. Walau bagaimanapun, minyak sayuran mempunyai kelikatan yang tinggi berbanding diesel konvensional yang tidak diingini. Kajian ini menumpukan kepada kajian prospek menggunakan minyak sayuran sebagai pengganti bahan api diesel dengan mengkonfigurasi eksperimen untuk menguji prestasi enjin dan untuk menentukan tahap pelepasan kepada tiga campuran bahan api minyak kelapa seperti 10%, 20% dan 30% daripada minyak kelapa - campuran diesel. Kajian yang dilakukan mengkaji parameter prestasi enjin dan ciri-ciri pelepasan untuk enjin diesel menggunakan campuran diesel kelapa tanpa sebarang pengubahsuaian enjin. Kajian dijalankan pada kelajuan enjin tetap 2500 rpm, dan kemudian ia secara beransur-ansur dimuatkan. Kajian ini telah dijalankan di lima beban, iaitu 0 bar (tanpa beban), 10 bar, 20 bar, 30 bar dan 40 bar. Bagi setiap keadaan beban enjin telah dijalankan sekurang-kurangnya 4-5 minit. Keputusan menunjukkan bahawa prestasi enjin asas seperti bekalan kuasa dan penggunaan bahan api adalah setanding dengan diesel. Apabila dibandingkan dengan bahan api diesel yang telah dicampurkan, penurunan terhadap penghasilan kuasa enijn telah ditemui dan terdapat peningkatan dan kadar penggunaan minyak bagi setiap minyak dengan peningkatan jumlah campuran minyak kelapa. Dalam kes pelepasan gas ekzos enjin, CO_2 yang lebih rendah dan NOx, manakala pelepasan CO dan HC lebih tinggi telah didapati untuk bahan api blended berbanding bahan api diesel.

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LIST OF ABBREVIATIONS

VCO	Vegetable Coconut Oil
WCO	Waste Cooking Oil
NGO	Non-governmental Organization
HC	Hydrocarbon
NOx	Nitrogen Oxides
NO	Nitrogen Oxide
NO_2	Nitrogen Dioxide
CO_2	Carbon Dioxide
CO	Carbon Monoxide
PM	Particulate Matter

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LIST OF SYMBOLS

°C	-	Temperature Degree
%	-	Percentage Emission
H_u	-	Calorific Value (kJ/kg)
P	-	Power (kW)
ρ	-	Density (kg/m^3)
p	-	Pressure (Pa)
Q_a	-	Volumetric Flow-rate (m^3/s)
ω	-	Angular Velocity (rad/s)
τ	-	Torque (Nm)
$\dot{m}$	-	Mass Flow-rate (kg/h)

CHAPTER 1

INTRODUCTION

1.1 Background

Petroleum oil the most important and abundantly available energy source, is largely consumed in the world. In a study by Ramadhas (2011) reviewed that on a daily average, over 43 million barrels are consumed by the industrialized country, while at the same time around 22 million barrels are being consumed by a developing country.

Table 1.1: World's Primary Oil Demand (Million Barrels Per Day)

	1980	2000	2006	2010	2015	2030	2006-2030 (%) p.a.
OECD	41.8	46.0	47.3	49.0	50.8	52.8	0.5%
North America	20.9	23.4	24.9	26.2	27.7	30.0	0.8%
Europe	14.7	14.2	14.3	14.5	14.7	14.7	0.1%
Pacific	6.3	8.4	8.1	8.3	8.3	8.1	0.0%
Transition economies	9.4	4.2	4.5	4.7	5.1	5.6	0.9%
Russia	-	2.6	2.6	2.8	3.0	3.3	0.9%
Developing countries	11.3	23.1	28.8	33.7	38.7	53.3	2.6%
China	1.9	4.7	7.1	9.0	11.1	16.50	3.6%
India	0.7	2.3	2.6	3.1	3.7	6.5	3.9%
Other Asia	1.8	4.5	5.5	6.2	6.9	8.9	2.0%
Middle East	2.0	4.6	6.0	7.0	7.9	9.5	1.9%
Africa	1.3	2.3	2.8	3.1	3.4	4.8	2.2%
Latin America	3.5	4.7	4.8	5.2	5.6	7.1	1.6%
Int. marine bunkers and stock changes	2.2	3.6	.1	3.7	3.9	4.5	-
World	64.8	77.0	84.7	91.1	98.5	116.3	1.3%
European Union	-	13.6	13.8	13.8	14.0	13.8	0.0%

(Source: Ramadhas, 2011)

Nowadays, the supply of petroleum has yet to suffice with its high demands due to its declining resources. In referring to the Malaysia's National Depletion Policy (1980) that prioritize to lengthen the nation's life span of oil and gas reserves, many research has been conducted to support the nation's goal.

On top of that, recent studies indicate that burning fossil fuel bring damages and harms to our eco system, thus, has raising many concerns among the public community. For example, it has been known that carbon monoxide emissions have been linked to climate changes. Unfortunately, burning of petroleum is a necessity for us to go about our daily day, even know that the toxic fumes produces by burning these fuels have led to problems such as asthma and other disorders due to exhausts from diesel. From these ever-growing needs of petroleum and its fatal effects to the society, an alternative solution in finding a sustainable energy sources are needed to ensure not only the safety of the people but also to help sustained its economic demands.

Scientist since have been rigorously conducting research on a cleaner, safer and greener option fossil fuel in their way of supplying the nation's demand, while battling the rise of global warming, immense level of pollution and climate change. Therefore, scientist have been looking at the possibility of renewable product's which could replace gasoline, diesel fuel and other pollutants. Recommendations of new and alternative energy resource are available. As a result, biofuel gets into the attention as a potential investment in supplying the world's need for energy without causing serious damages to the environment.

Apart from focusing on finding the most viable alternative fuels, there are other aspects that need to be taken into consideration. Therefore, to establish innovative technologies for highly effective utilization of energy, fundamental research must be conducted in the following areas.

1.2 Problem Statement

Since the early 1900 many scholars have forecasted the fossil fuel source will soon be depleted (Deffeyes, 2005). This problem has been made certain as the needs for non-renewal energy sources is growing rapidly. Due to the condition of today's fuel depletion, there is a huge incapability to keep up with the current necessity. Industries are facing the ever-growing demands for a liable energy source. If this continues to rise in the future, the demand to supply ratio of non-renewable energy sources would be unbalanced which can lead to energy crises. Therefore, the idea of using vegetable oil for substitution and as an alternative fuel is suggested.

Rudolph Diesel have used peanut oil in a compression ignition engine to demonstrate the use of vegetable oil in his engine (Paterson et al.,1990). However, it is found that a through a prolong test of using the vegetable oil in the engine have led to injector coking and the thickening of crankcase which resulted in piston ring sticking. These problems are expected to be the result of the high viscosity and non-volatile properties of the vegetable oil which are determined can led to insufficient fuel atomization and incomplete combustion. Therefore, this have led to a conclusion that the vegetable oils cannot be use directly in direct injection diesel engines.

Moreover, fossil fuel over-consumption has led to serious environmental issues such as global warming and air pollution. There have been many studies conducted which emphasize on the importance of reducing the amount of harmful gasses emission such as nitrogen oxide (NO_x), hydrocarbon (HC), carbon dioxide (CO_2) and carbon monoxide (CO), which are found to be among the leading cause of climate change, global warming and huge increase in the level of pollution. Therefore, by changing from the use of fossil sources to renewable energy sources can greatly reduce the effect global warming and other issues,

renewable energy sources have better dispersal than fossil resources and does far less environmental harm and social concerns (Cherubini & Stromman, 2011).

Hence, to overcome this problem and avoid these incidents, the blending of fuel is a solution to decrease the high viscosity of vegetable oil. Therefore, this research will be conducted to test several fuel blends formula of vegetable oil and diesel with 10%, 20% and 30% ratio to reduce the viscosity of the vegetable oil. In every test, fuel consumption during the running condition and exhaust gas emission such as nitrogen oxide (NO_x), hydrocarbon (HC), carbon dioxide (CO_2) and carbon monoxide (CO) are measured. This research will determine which percentage of mixed between diesel and vegetable oil would provide the most fuel efficiency and low emission.

1.3 Objectives

This project aims to achieve several objectives. These objectives are used as a guideline to gain better results in this research. The research objectives of this study are:

i To study the performance and the exhaust emission characteristics of the diesel engine.

ii To investigate the diesel engine fueled with vegetable oil and its blends, and compared to those of ordinary diesel fuel.

iii To investigate the effect of the variation of the diesel blend ratio, towards the engine's performance and exhaust emission.

1.4 Scope of Study

The scope of this project is divided into 3 parts i.e. sampling process, engine test performance and exhaust gas emission. Below are the detail descriptions of the scope of this research:

i. Sampling Process

There will be several blends of vegetable and diesel oil with the percentage of fuel blends of vegetable oil such as 10%, 20%, and 30%.

ii. Engine Test Performance

The engine will be put on several testing conditions to know the engine's performance while running on the mixed fuel.

iii. Exhaust Gas Emission

Exhaust gas from the engine will be analyzed to determine the level of toxicity present in the combustion by-product. This include, nitrogen oxide (NO_x), hydrocarbon (HC), carbon dioxide (CO_2) and carbon monoxide (CO).

The method of the test will be discussed in the project. The chemical reaction of the combustion process is outside the scope of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Vegetable Oil

When the first energy crisis arose in the 1970's, the research on vegetable oil for fuel purposes had begun once again. Rudolph Diesel has demonstrated that his engine is capable to run using peanut oil in a compression ignition engine to demonstrate the use of vegetable oil in his engine (Ramadhas, 2011).

Due to price of vegetable oil fuel to be more expensive compared to petroleum fuels led to its inability to compete with the current market fuel. However, there are high possibility that vegetable oils and derivatives have the potential to replace a fraction of distillate petroleum and petrochemical petroleum-based. Furthermore, using vegetable oil as a fuel can greatly enhance farm incomes and improve rural economies.

Vegetable oil has a heat content of about 90% of the diesel fuel and the potential of alternative fuels. However, Saravanan et al. (2007) and Schwab et al. (1987) found that a major obstacle that is preventing the use of vegetable oil in the direct-injection diesel engine would be due to its level of viscosity, which are found to be almost 10 times higher as compared to conventional diesel fuel. Due to the facts that raw vegetable oil is not biodiesel, which is the ester of vegetable oil produced through a process called transesterification. This results in poor fuel atomization and improper mixing with air, which in turn results in inefficient combustion. Vegetables oil fueled engine requires frequent maintenance.

This is literature review is about the viability of using vegetable oil as a replacement for diesel fuel. Note that, the term vegetable oil discussed refers to vegetable oil that have not been modified through transesterification or similar processes resulted to a product called biodiesel.

2.1.1 Palm Oil

There are two distinctive types of oil which are produced by the palm fruit, one would be palm oil and the other is palm kernel oil. There are major different between these two types of oil. For example, palm oil is produced through the extraction from the pulp of the fruit, it is edible and are largely used the food industry. Whereas, the palm kernel oil is produced through the extraction process from the seed and are most likely used for the manufacturing cosmetics and soaps, while the by-product of the extraction processes a used for feeding of livestock and biofuel. While on the on the other hand, palm oil is highly productive, able to produce more oil with less lass as compared to any other vegetable, with relatively modest inputs. As a result, palm oil production has become an important source of income and a major part of the economy in the regions where it is grown, providing the locals with sustainable income and boost its economics.

As one of the largest world's producers and exporters of palm oil and products, Malaysia is accountable for 39% of the world's production of palm oil and 44% of the world's export. The Figure 2.1 shows the areas of palm plantation in Malaysia in terms of hectares' square from the year 2010 till 2015. The finding indicates that this plant is largely grown in the peninsular Malaysia as compared to Sabah and Sarawak.