Faculty of Mechanical Engineering

PERFORMANCE AND EMISSIONS STUDY OF A SINGLE CYLINDER CI ENGINE USING CASTOR OIL BIODIESEL

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DECLARATION

I declare that this thesis entitled "Performance and Emissions Study of A Single Cylinder CI Engine using Castor Oil Biodiesel" 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 : MOHD ZAINI BIN JAMALUDIN

Date : .....

APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment of Master of Science in Mechanical Engineering.

Signature : ……

Supervisor Name : DR. SAFARUDIN GAZALI HERAWAN

Date : ……

DEDICATION

To my beloved father, mother, brother, sister, friends, lecturers and Allah S.W.T.

ABSTRACT

Since the scarcity of fossil fuel, an increase in oil prices and food crisis in the past, several techniques have been proposed for the production of this fuel which is totally or partially derived from renewable feedstock. This interest led to expose a renewable fuel that would supplement the current reserves, either directly or indirectly. Biodiesel is a substitute to conventional diesel fuel made from renewable resources, such as non-edible vegetable oils. The purpose of this study was to investigate the effects of biodiesel fuel derived from Castor oil blended with petro-diesel fuel at various blending ratios on performance and emissions. This study used a small four strokes diesel engine that operates through varied engine speeds at 1500, 2000, 2500, 3000, 3500 and 3600 rpm under 0, 50 and 100 % dynamometer loads condition with an emission gas analyser attached to the exhaust pipeline. Data for this study were collected from experimental in term of power, torque, fuel consumption and gases emissions. Four samples were selected from Castor oil biodiesel which are B5, B10, B20, and B25 and diesel. On the basis of the results of this research, it can be concluded that the Castor oil biodiesel has a potential to be used as an alternative to replace biodiesel made from food (edible) source.

ABSTRAK

Sejak kekurangan bahan api fosil, kenaikan harga minyak dan krisis makanan pada masa lalu, beberapa teknik telah dicadangkan untuk pengeluaran bahan api ini yang secara keseluruhan atau sebahagiannya diperolehi daripada bahan mentah yang boleh diperbaharui. Daya tarikan ini membawa kepada pendedahan bahan api yang boleh diperbaharui yang akan menambahkan bekalan semasa sama ada secara langsung atau tidak langsung. Biodiesel adalah pengganti bagi bahan api diesel konvensional yang diperbuat daripada sumber boleh diperbaharui, seperti minyak sayuran yang tidak boleh dimakan. Tujuan kajian ini adalah untuk menyiasat kesan bahan bakar biodiesel yang diperolehi dari minyak kastor yang diadun dengan bahan bakar petro-diesel dengan pelbagai nisbah campuran pada prestasi dan pelepasan telah dilakukan. Kajian ini menggunakan enjin diesel bersaiz kecil jenis empat lejang yang beroperasi melalui enjin pembolehubah pada kelajuan 1500, 2000, 2500, 3000, 3500 dan 3600 rpm di bawah 0, 50 dan 100% beban dynamometer dengan penganalisis gas pelepasan yang dilekatkan pada saluran paip ekzos. Data untuk kajian ini dikumpulkan dari eksperimen adalah kuasa, daya kilas, penggunaan bahan api dan pelepasan gas. Empat sampel dipilih daripada biodiesel minyak kastor iaitu B5, B10, B20, B25 dan diesel. Berdasarkan hasil penyelidikan ini, dapat disimpulkan bahawa biodiesel minyak kastor mempunyai sumber potensi untuk digunakan sebagai alternatif dan untuk menggantikan biodiesel yang terbuat dari sumber makanan (dapat dimakan).

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LIST OF SYMBOLS

H_2SO_4	-	Sulfuric acid
NaOH	-	Sodium hydroxide
SO_2	-	Sulfur dioxide
NO_x	-	Nitric oxide and nitrogen dioxide
CO	-	Carbon monoxide
CO_2	-	Carbon dioxide
H_2O	-	Water
O_3	-	Ozone
HC	-	Hydrocarbon
N_2O	-	Nitrus oxide
Cp	-	Centipoise
Cst	-	Centistokes
$\dot{m}$	-	Mass flow rate
$^{2}{}_{th}$	-	Torque at pump's shaft
P_b	-	Pump pressure
V_d	-	Pump displacement
$\dot{W}$	-	Power of the engine
N	-	Engine revolution

LIST OF ABBREVIATIONS

CI	Compression ignition
DI	Direct injection
BSFC	Brake specific fuel consumption
BSEC	Brake specific energy consumption
RPM	Revolution per minute
FFA	Free fatty acid
FAME	Fatty acid methyl ester
GHG	Greenhouse gases
EN	European norms
ASTM	American society for testing and materials
MPOB	Malaysian palm oil berhad
NBP	National biofuel policy
PME	Palm methyl ester
MS	Malaysia standard
GOM	Government of malaysia
MPIC	Ministry of plantation industry and commodities
COME	Castor oil methyl ester
NA	Naturally aspirated

LIST OF PUBLICATION

1. **M. Z. Jamaludin**, S. G. Herawan, M. A. Yusmady, A. Fauzi, *Performance Comparison between Diesel Fuel and Biodiesel Using a Low Cost Single Cylinder Diesel Engine Dynamometer*, Applied Mechanics and Materials, Volume 554, pp. 505-509, Jun 2014.

2. **M. Z. Jamaludin**, S. G. Herawan, M. A. Yusmady, *Performance and Emission Characteristics of Castor Blends Biodiesel in Single Cylinder Diesel Engine Dynamometer*, Proceedings of Mechanical Engineering Research Day 2015, pp. 123-124, March 2015.

3. **M. Z. Jamaludin**, S. G. Herawan, M. A. Yusmady, *Performance and Emission Evaluation of Castor Blends Biodiesel in Single Cylinder Diesel Engine Dynamometer*, Jurnal Teknologi (Science & Engineering), Volume 77:21, pp. 91-95, September 2015.

CHAPTER 1

INTRODUCTION

1.1 Overview

In recent years, the use of biodiesels as alternative fuels has been extensively investigated with the objective of ensuring energy security and reducing the environmental impacts of diesel emissions. Recently, the European Union voted against a biofuel production using the first-generation biofuel sources (edible oils) such as palm oil, corn, soybean, and maize that are also consumed as food. This opens a new avenue of producing biodiesel using non-food source crops such as forest seeds (i.e. *callophylum innophylum L.*, *Elateriospermum tapos*, *Hevea Brasiliensis*) which would be utilised in this work. In Malaysia, there are 18,869,000 tonnes of palm oil plantations as of 2014 (Department of Statistics Malaysia). Comparing to the palm oil biodiesel industry, biodiesel produced from Castor is still in its nascent state in Malaysia even though considerable interest has been shown by the government and private sectors. Castor oil is a member of the spurge family of plants Euphorbiaceaae. Castor is non-edible and one advantages of castor is that it is well adapted to arid conditions and can stand long periods of drought.

The investigation of the production of biodiesel from non-edible feedstock and its effects on performance and emissions on compression ignition diesel engine are of great interests. Castor oil was used as a raw material for the biodiesel production. In addition to biodiesel production, engine performance and exhaust emission experimental studies were

performed. The objective of this study was to explore the utility of castor oil blends as a potential source of biodiesel fuel.

1.2 Problem statement

Nowadays, petroleum diesel from fossil fuel is limited and non- renewable. Biodiesel is one of the promising alternative fuels, which is renewable and environmental friendly. Biodiesel fuel has a huge potential to be used as an alternative fuel which can reduce the total emission of carbon dioxide (CO_2) from inside the internal engine. The biodiesel fuel in this study was made from castor oil. Biofuels based on vegetable oils offer the advantage of being a sustainable, annually renewable source of diesel engine fuel, and receive a lot of attention. However, there is limited information available on the effect of castor oil biodiesel blended ratio on engine assessment and emissions. Therefore, this research focused on the ratio of blending Castor biodiesel to obtain optimum performance and reduce emission.

1.3 Objectives of study

The objectives of the study as follows:

i. To examine the effect of various biodiesel blending ratios on performance and emission of compression ignition (CI) engine.
ii. To recommend the biodiesel blending ratio that optimises the engine performance and lower exhaust emissions.

1.4 Scope of study

The scopes of work in accomplishing this research were:

i. The fuels test performed using a small engine CI diesel engine: Kipor model KM 170F, 211 cc, 1 cylinder, in-line, air cooled, 4-strokes.

ii. The fuels tested were the standard diesel fuel and biodiesel blends with standard diesel engine.

iii. The castor oil based with various blended rates used were 5%, 10% 20%, and 25% by volume.

iv. The test was carried out at four different engine speeds at 1500 rpm, 2000 rpm, 2500 rpm, 3000 rpm and 3500 rpm as well as various load conditions applied at 0%, 50% and 100%.

1.5 Significance of this Study

This study was based on the investigation of biodiesel fuel derived from Castor oil. The blending fuel quantities with diesel fuels by volume were as per stated below:

i. CO5 (5% Castor biodiesel oil, 95 % standard diesel),

ii. CO10 (10% Castor biodiesel oil, 90 % standard diesel),

iii. CO20 (20 % Castor biodiesel oil, 80 % standard diesel), and

iv. CO25 (25 % Castor biodiesel oil, 75 % standard diesel).

From the biodiesel fuels production and mixtures, one of the most important criteria of biodiesel such as fuel viscosity were analysed due to its significant control of the combustion quality during air-fuel premixing at the early process of combustion which resulted in either shortened or prolonged ignition delay. The outcome of this research is very important for future research and development as a direction to establish alternative fuels that signify lower emissions and yet less dependent on fossil fuel.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides an overview of the context for this thesis. The mechanism of global warming and its effects are briefly explained. The international and national policies to encourage the substitution of biofuels into the petroleum dominating road transports fuel supply as well as. The assessment methods to ascertain the contribution of biodiesel towards suitability are presented. Finally, biodiesel is discussed in greater details in terms of the process making production, evaluated performance and exhaust emissions. This subject of biodiesel has generated a considerable volume of literature that includes some experiments conducted to explain the characteristics of biodiesel.

2.2 Greenhouse gasses

Global warming refers to the increased temperature of the earth surface by greenhouse gasses Carbon dioxide (CO_2), carbon monoxide (CO), water vapour (H_2O), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3) are examples of greenhouse gases. CO_2 is the main greenhouse gas which is an unavoidable product of economic activities and human activities. In fact, the potential of global warming is created from many factors which are natural and man-made causes (Hofstrand, 2013). Transportation emission especially from diesel engine contributes to a direct (CO_2) and indirect (NO_x, and CO) warming impact. Table 2.1 illustrates a global warming impact from alternative technology vehicles.