DEVELOPMENT OF AN ATMOSPHERIC COMBUSTOR TEST RIG FOR FIRING ENVODIESEL BLENDS

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To my beloved mother, father and husband

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ABSTRACT

Liquid fuel combustion contributed to air pollution and global warming problems. Combustion using fossil fuel e.g. petroleum diesel produces high concentration of emissions such as carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxide (NOx) and sulphur dioxide (SO_2). Palm biodiesel consists of palm methyl ester and diesel has been used to reduce the emission value. However, the production of biodiesel is expensive. Therefore, the direct blending method of palm olein and diesel has been used to produce envodiesel without using the transesterification process. The properties and characteristics of envodiesel have been studied in order to determine the fuel performance during combustion. A 500 mm length and 152 mm diameter of combustor has been fabricated using stainless steel tube for firing the envodiesel blends. Thermocouples type-K are placed axially along the combustor length to measure the wall temperatures. Besides that, the gas analyzer probe has been used to measure the emission gas during the testing. An axial swirler of 45º angle with 8 blades, fuel injector system, electrode copper igniter system, air blower and super heater are installed in the combustion system to burn the envodiesel blends. As a result, envodiesel blends with 5% palm olein and 95% diesel (B5) has higher wall temperature as compared to other blends. The result shows the various percentages of envodiesel blends decrease the CO_2, CO, NOx and SO_2 emission. The B25 has lowest of CO_2, CO, NOx and SO_2 values of 3%, 492 ppm, 8 ppm and 9 ppm respectively. It can be concluded the envodiesel blends have lower emissions compared to diesel fuel.

ABSTRAK

Pembakaran bahan api cecair menyumbang kepada masalah pencemaran udara dan pemanasan global. Pembakaran yang menggunakan bahan api fosil seperti minyak diesel telah menghasilkan kepekatan emisi yang tinggi seperti karbon dioksida (CO_2), karbon monoksida (CO), oksida nitrogen (NOx) dan sulfur dioksida (SO_2). Minyak sawit biodiesel yang mengandungi metil ester sawit dan diesel telah digunakan untuk mengurangkan kadar pembebasan gas emisi. Walaubagaimanapun, kos penghasilan minyak biodiesel adalah tinggi. Oleh itu, kaedah pengadunan langsung telah digunakan untuk menghasilkan minyak sawit diesel (envodiesel) tanpa melalui proses tindak balas pentransesteran. Ciri-ciri dan sifat minyak sawit diesel telah dikaji bagi mengenalpasti potensi minyak ini dalam pembakaran. Kebuk pembakaran sepanjang 500 mm telah dihasilkan menggunakan tiub keluli tahan karat berdiameter 152 mm untuk membakar minyak sawit diesel. Pengganding-haba jenis-K diletakkan secara memaksi di sepanjang kebuk pembakaran untuk merekodkan suhu dinding. Selain itu, alat pengukuran emisi juga digunakan untuk mengukur kadar pembebasan gas semasa eksperimen dijalankan. Pemusar udara aliran paksi dengan sudut 45 darjah dan 8 bilah, muncung semburan bahan api, percikan api jenis tembaga elektrod, alat pembekal udara dan pemanas udara telah dipasang pada alat ujikaji pembakaran bagi membakar adunan minyak sawit diesel. Keputusan ujikaji mendapati adunan 5% minyak sawit dan 95% minyak diesel mempunyai suhu dinding kebuk pembakaran yang tinggi berbanding adunan minyak sawit diesel yang lain. Keputusan menunjukkan minyak sawit diesel berbagai adunan telah mengurangkan kadar pembebasan gas emisi. Minyak sawit diesel (B25) mengurangkan kadar pembebasan gas emisi sebanyak 3%, 492 ppm, 8 ppm dan 9 ppm bagi gas karbon dioksida, karbon monoksida, oksida nitrogen dan sulfur dioksida. Kesimpulannya minyak sawit diesel mempunyai kadar pembebasan gas emisi yang rendah berbanding minyak diesel.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

A	-	Pipe area
Act	-	Actual
A/F	-	Air fuel ratio
Cv	-	Calorific value
cst	-	Centistoke
d	-	Pipe diameter
f	-	Friction
g	-	Gravity
hf	-	Head loss
hr	-	Hour
J	-	Joule
K	-	Kelvin
kg	-	Kilogram
kV	-	Kilovolt
kW	-	Kilowatt
L	-	Liter
l	-	Pipe length
MJ	-	Megajoule
MPa	-	Megapascal
m	-	Meter

mm	-	Milimeter
$\dot{m}_a$	-	Mass flowrate air
$\dot{m}_f$	-	Mass flowrate fuel
m^3	-	Metercube
m^3/hr	-	Metercube per hour
N	-	Newton
P	-	Pressure
Pa	-	Pascal
ppm	-	Parts per million
Q	-	Flow rate
Re	-	Reynold number
Stoic	-	Stochiometric
s	-	Second
T	-	Temperature
V	-	Voltage
v	-	Pipe velocity
x/L	-	Combustor length
μ	-	Dynamic viscosity
p	-	Density
ΔP	-	Pressure loss
ε	-	Roughness of the piping
Ø	-	Equivalent ratio
%	-	Percentage
μm	-	Micrometer
ΣK	-	Minor friction loss

LIST OF ABBREVIATIONS

ABBREVIATION		FULL NAME
B0	-	100 % Diesel Fuel
B5	-	5 % Palm Olein with 95 % Diesel (Envodiesel)
B10	-	10 % Palm Olein with 90 % Diesel (Envodiesel)
B15	-	15 % Palm Olein with 85 % Diesel (Envodiesel)
B20	-	20 % Palm Olein with 80 % Diesel (Envodiesel)
B25	-	25 % Palm Olein with 75 % Diesel (Envodiesel)
C	-	Carbon
CO_2	-	Carbon Dioxide
CO	-	Carbon Monoxide
H	-	Hydrogen
HHV	-	High Heating Value
LHV	-	Low Heating Value
N	-	Nitrogen
NOx	-	Nitrogen Oxide
O	-	Oxygen
RBDPO	-	Refined, Bleached, Deadorized Palm Olein
SMD	-	Sauter Mean Diameter
SO_2	-	Sulphur Dioxide

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Petroleum oil and natural gas are fossil fuels that have been used to generate energy for power plant, transportation, industrial and others. Petroleum oil e.g. diesel fuel has been used in power plant because of its potential to generate high power energy [1]. However, the price of fossil fuel is very high due to the demands usage of this fuel. Combustion of fossil fuel tends to form pollutant gases. Fossil fuel increases the carbon monoxide, carbon dioxide, sulphur dioxide, nitrogen oxide and other emissions when burned [2]. Therefore, biodiesel is a promising fuel because of its ability to reduce emission during combustion. Palm methyl ester is one of the biodiesels used in combustion that could replace the diesel fuel. Transesterification is the method used to produce palm methyl ester [3]. However, the transesterification method is costly. Because of that, direct blending method is inexpensive method used to mix the vegetable oil with petroleum diesel. The fuel produced from this method is called envodiesel. In this research, properties and characteristics of envodiesel are investigated using a combustor test rig device in order to reduce the emission and also to reduce the cost of fuel production.

1.2 Problem Statements

The diesel fuel is usually used in combustion to generate energy for industrial transportation and others. Diesel fuel could generate high power energy and high efficiency when burned [4]. Because of its potential to generate energy for every application, diesel fuel becomes demanded source energy. However the combustion of diesel fuel contributes to emission gases e.g. carbon monoxide, carbon dioxide, nitrogen oxide, sulphur dioxide and others. Liberation of these gases has a great potential of an air pollution, greenhouse effect and global warming in this country. If the problem persists, the air quality in this country will be more contaminated with harmful gases and may also cause health problems to human.

In Malaysia, there is million tons of palm oil produced per year for various kinds of products [5]. Therefore, it has been chosen due to the availability of this oil for used in combustion application. This fuel known as an envodiesel consists of palm olein that produced from palm oil. Based on previous study, the envodiesel blends have lower carbon content which reduced the emission gases during combustion [6]. Besides that, palm oil is clean and biodegradable [7]. Thus, the properties and characteristics of envodiesel were studied in order to determine the fuel performance during combustion. The testing was conducted using the atmospheric combustor test rig device.

1.3 Objectives

The objectives of the research are:

1. To determine the properties (calorific value and ultimate analysis) of envodiesel blends.
2. To fabricate the atmospheric combustor test rig for firing envodiesel blends.
3. To analyze the behavior of wall temperature and emission at various pre-heated air in order to identify the performance of envodiesel blends during combustion.

1.4 Scopes

The scopes of the research are:

1. Preparation of the testing apparatus:
    i. Air blower
    ii. Super heater
    iii. Thermocouple reader and sensor
    iv. Gas analyzer
2. Fabricate the atmospheric combustor test rig laboratory scale. The component of fabrication includes:
    i. Air supply system
    ii. Combustion chamber
    iii. Igniter system
    iv. Fuel injector system
    v. Axial swirler

3. Blending of palm olein and diesel, as producing envodiesel blends using direct blending in order to determine the properties at different percentages.
4. Testing the envodiesel blends using different pre-heated atmospheric air temperature.

1.5 Thesis Outline

The thesis is divided into five chapters. Chapter 1 includes the problem statement, objectives and scopes of this research.

Chapter 2 is the literature study of this research. This study focuses on the physical and chemical properties of diesel, palm oil biodiesel and envodiesel blends. The fuel properties are the parameters that affected the combustion characteristics such as wall temperature profile and emission. Besides that, the standard combustor test rig and burner system have been studied in order to burn envodiesel blends fuel.

Chapter 3 describes the experimental apparatus, modification of combustor test rig design, fuel preparation and experimental procedures.

Chapter 4 comprises the combustor wall temperature and emission results using different envodiesel blends. The wall temperature, carbon dioxide, carbon monoxide, nitrogen oxide and sulphur dioxide emission results are recorded using thermocouple reader and gas analyzer during experiments. The testing is carried out using 5%, 10%, 15%, 20% and 25% of envodiesel blends at various pre-heated air temperatures.

Chapter 5 is the conclusion and recommendations of this research. This chapter explains the overall results that have been obtained. The effectiveness of envodiesel is concluded, while the potential of envodiesel in combustion elaborated based on the wall temperature and emission results that obtained from standard combustor test rig. Besides that, some recommendations have been explained in order to improve this research.

1.6 Research Methodology

The flow of research methodology is shown in Figure 1.1.

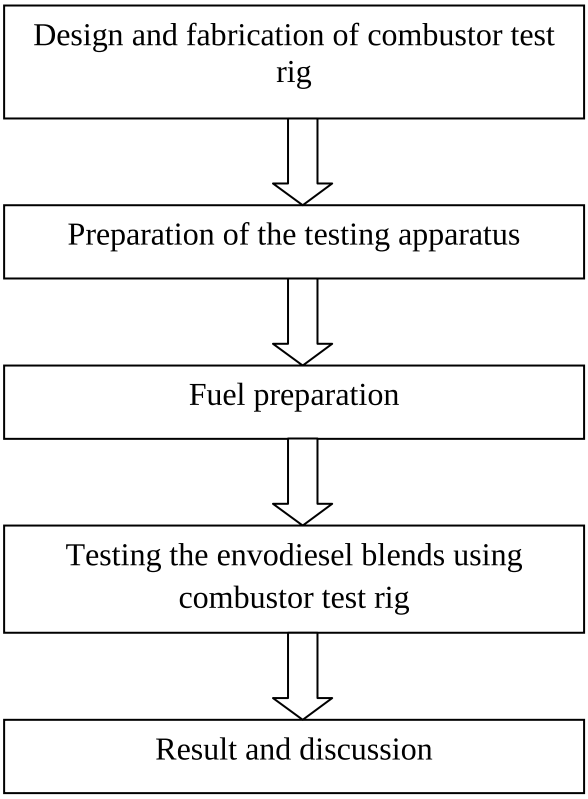

Figure 1.1: Flow of research methodology

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