A STUDY ON 5 % AND 10 % BIO-BLENDED DIESEL FUEL SPRAY DEPOSITION

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"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 (Automotive) with Honour"

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This project is submitted to
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DECLARATION

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

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ABSTRACT

Deposit formation inside a combustion chamber is a phenomenon that contributes to various engine problems such as increase in emission, engine performance reduction as well as engine damage. Due to higher viscosity, density and distillation temperature compared to diesel fuel, utilization of bio-diesel fuel increase the tendencies of deposit formation. The aim of this study is to investigate the deposit formation for 5 % and 10 % Bio-Blended Diesel Fuel (B5 and B10) using Fuel Spray Deposition Test (FSDT) apparatus. The deposit formation on hot surface depends on spray interval, fuel types, wall surface temperature, chemical reaction effect, heat transfer effect and cooling effect. Existing FSDT apparatus had been improved and experiment had been conducted successfully for surface temperature of 300 °C. In this study, it was found that deposition mass of both tested fuels was increased. Deposition mass of B10 was found to be higher than B5, due to higher value of density and viscosity. Deposit formation rate for both fuels was decreasing as a function of time. However, B10 have higher deposit formation rate as compared to B5 over time. Fuel deposit pattern onto the hot surface for both fuels differs to each others, due to the atomization ability of the fuels. Hence, the utilization of lower blends percentage of bio-diesel fuels had greater potential in reducing deposit formation on a combustion chamber wall in an engine.

ABSTRAK

Pemendapan dalam kebuk pembakaran ialah fenomena yang menyumbang kepada masalah terhadap enjin seperti peningkatan emisi terhadap persekitaran, pengurangan prestasi enjin dan kerosakan dalam enjin. Disebabkan bio-diesel mempunyai kelikatan, ketumpatan dan suhu penyulingan yang lebih tinggi daripada minyak diesel, penggunaan minyak bio-diesel dalam pasaran telah meningkatkan kecenderungan dalam pembentukan pemendapan. Tujuan kajian ini adalah untuk menyiasat pembentukan pemendapan bagi 5 % dan 10 % campuran bahan api Bio-Diesel (B5 dan B10) dengan menggunakan radas Ujian Pemendapan Semburan Bahan Api (FSDT). Pembentukan pemendapan terhadap permukaan panas bergantung kepada selang masa semburan, jenis bahan api, suhu permukaan, tindak balas kimia, kesan pemindahan haba dan kesan penyejukan. Radas FDST telah dibaik pulih dan ujikaji telah selesai dijalankan bagi suhu permukaan 300 °C. Dalam kajian ini, didapati bahawa jisim pemendapan bagi kedua-dua bahan api yang diuji menunjukkan peningkatan. Disebabkan ketumpatan dan kelikatan yang lebih tinggi, B10 menghasilkan jisim pemendapan yang lebih tinggi daripada B5. Kadar pembentukan pemendapan bagi kedua-dua bahan api berkurang dengan masa. Tetapi, B10 mempunyai kadar pembentukan pemendapan yang lebih tinggi daripada B5, berkadar dengan masa. Corak pemendapan bagi kedua-dua bahan api menunjukan perbezaaan disebabkan oleh keupayaan pengabusan bahan api tersebut. Maka, penggunaan bahan api yang mempunyai peratusan pencampuran bio-diesel yang lebih rendah mempunyai kecenderungan dalam pengurangan pembentukan pemendapan pada dinding kebuk pembakaran bagi sesuatu enjin.

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Material
BHA	Butylated Hydroxyanisole
BHT	Butylated Hydroxytoluene
CI	Compression Ignition
CN	Cetane Number
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CSO	Cottonseed Oil
CSOME	Cottonseed Oil Methyl Ester
D2	No.2 Type Diesel Fuel
DC	Direct Current
FAME	Fatty Methyl Esters
FSDT	Fuel Spray Deposition Test
HC	Hydrocarbon
HCCI	Homogeneous Charge Compression–Ignition
HP	Horsepower
HSDI	High Speed Direct Injection
ID	Ignition Delay
La	Laplace Number
max	Maximum
MEP	Maximum Evaporation Rate Point
min	Minimum
NO_x	Nitrogen Oxides
PF	Poultry Fat Based
PM	Particulate Matter
PME	Palm Methyl Ester
PrG	Propyl Gallate

LIST OF ABBREVIATIONS

PSM	Projek Sarjana Muda
SAE	Society of Automotive Engineers
SBO	Soybean Oil
SG	Specific Gravity
SP	Spray Penetration
TBHQ	Tert-Butylhydroquinone
USA	United States of America
UTeM	Universiti Teknikal Malaysia Melaka
vol	Volume
We	Weber Number
wt	Weight

LIST OF SYMBOLS

L	Length	[m]
ℓ	Characteristic Length	[m]
μ	Viscosity	[mm^2/s]
t	Time	[s]
ρ	Density	[kg/m^3][g/ml]
v	Velocity	[m/s]
σ	Surface Tension	[kg/s^2]
V	Voltage	[V]

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Development of diesel engine had been evolved dramatically since its invention around 1900's. Throughout the industrial revolution era, diesel engine had made its important roles and been widely used especially in transportation fields such as heavy trucks, heavy machineries and most importantly, commercial vehicles. Diesel engine had many advantages than gasoline type engines: high power-to-weight ratio, higher thermal efficiencies, better fuel economies, simpler construction and most importantly lower hydrocarbons (HC) emission.

However, emission from burned diesel fuel had brought major drawbacks since it produce particulate emissions such as sulfates from sulfur contents inside the fuel **[1]**, as much as 20 to 50 times higher than conventional petrol-diesel **[2]**. This had brought major concerns since it is harmful to the environments and most importantly to publics. Typical proposed low-emissions fuel should have high cetane number (CN), low boiling range, low aromatic compound and addition of oxygenates **[1]**. Hence, some of the researchers had started to developing new alternatives fuels from vegetable oils and cooking oils to produce bio-diesel. Bio-diesel, an alternative fuel from diesel, is known as fatty acid methyl or ethyl esters formed from vegetable oils or animal fats with alcohols through transesterification process **[3]**. It is renewable, bio-degradable and oxygenated compared to conventional diesel fuel **[4]**. With the implementation of bio-diesel into the market, this had eventually reduced the needs from fossil fuels which is depleting throughout the years.

1.1.1 Bio-Diesel Fuel

Bio-diesel (chemical name: fatty acid methyl esters (FAME), C_{14}-C_{24} methyl esters, is defined as a fuel comprised of mono-alkyl esters of long–chain fatty acids derived from renewable lipid feedstock, such as vegetable oils or animal fats, for used in compression-ignition (CI) diesel engine **[5]**. It is a type of alternative fuel that had the potential to reduce emissions and green house effect. It is known as "advanced bio-fuel" through the Energy Independence and Security Act of 2007 **[3]**.

Bio-diesel is produced from transesterification process by reaction of fatty acids such as glyceride with alcohol in presence of catalyst. The produced product, which is long chain fatty acids that comprise of alkyl esters and glycerol.

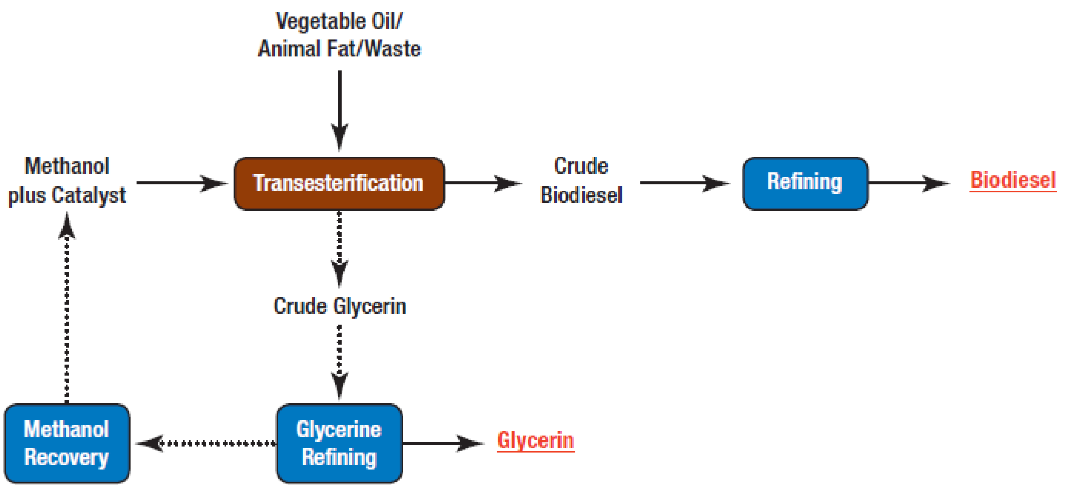

Figure 1.1 Basic Transesterification Process **[6]**

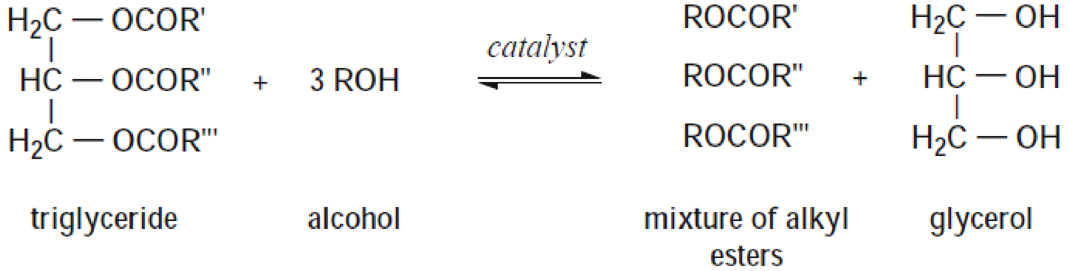

Figure 1.2 Transesterification of triglycerides with alcohol **[2]**

Bio-diesel usually blended with petroleum diesel to make bio-diesel blends; B100 is pure FAME, while B20, B5 and B2 are fairly common blend levels **[3]**. Bio-diesel blends are classified through the letter B with followed numbers that denotes the percentage of bio-diesel in the blend. For example, B20 of bio-diesel is consists of 20 % of bio-diesel blends inside the fuel. However, for the conventional and unmodified diesel engine, it can only operate with maximum of 20 % bio-diesel blended fuel **[7]**.

1.1.2 Fuel Deposition

Inside combustion chamber, large amount of fuel droplet was produced during fuel injection process. This droplet will experience atomization and eventually burned inside combustion chamber. However, due to some properties inside engine such as ignition delay (ID) or excessive amount of fuel droplet, some of the fuel droplet will not eventually burned up and cause impingement onto the wall surface of combustion chamber and piston head. This repeating process will in turn produce liquid fuel films **[8]**, where deposit formation will produce onto combustion chamber wall surface. Figure 1.3 below shows the common fuel deposits on top of the piston bowl inside common diesel engine.

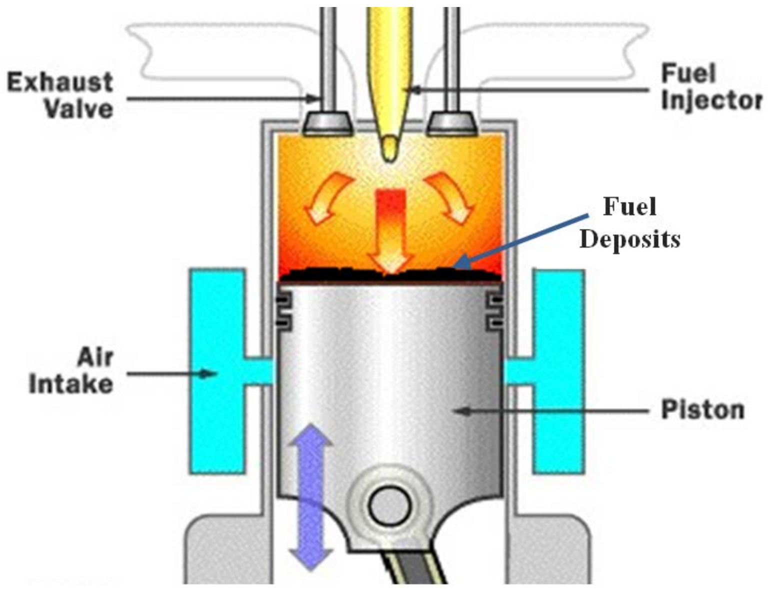

Figure 1.3 Fuel Deposition phenomena inside combustion chamber **[9]**

According to Werlberger and Cartellieri **[10]**, they discovered that for small bore direct injection diesel engine, more than 50 % of the fuel will impinged on the top of piston bowl at high load conditions.

Inside small diesel engine, probability of impingement onto wall surface was higher, due to factors such as higher injection pressure that leads to higher spray penetration of fuel droplet **[11]**, longer ID as compared to injection period **[12]**, small engine with smaller stroke between injector nozzle and piston head **[13]**, and incomplete combustion causing unburned fuel droplets, especially in the case for bio-diesel fuel **[2]**.

Wall surface temperature plays major role in fuel impingement. Higher wall surface temperature will have less fuel impinge onto it than lower wall surface temperature as discovered by Tang *et al.* in the case for bio-diesel **[14]**. Higher volatility and heavier molecular mass fuel (density) will more likely to produce more impingement on wall surface as experimental results discovered by Tat and Gerpen **[15]**.

1.2 PROBLEM STATEMENT

Engine deposition is the phenomena where deposit forms from unburned fuels inside the combustion chamber. This in turns leads to increase in emission and reduce engine performance **[16]**. Wall surface temperature was found to be one of the main factors that affect the amount of deposit accumulated **[14]**.

In this study, Fuel Spray Deposition Test (FSDT) was used to conduct an experiment to investigate the deposit formation of B5 and B10 due to fuel spray impingement on a hot surface.

1.3 OBJECTIVES

The main objective of this research is to investigate the deposit formation tendency for bio-blended diesel (B5 and B10) fuel spray on a hot surface plate.

1.4 SCOPES

This study was focused on the investigation of deposit formation for B5 and B10 on a hot surface due to fuel spray impingement. At first, the current design of FSDT apparatus, fabrication method, as well as properties and behavior of fuel are studied. Then, the current apparatus was improved and experiments were conducted for further investigation.

The main scopes of this study are summarized as below:

i. Modify the existing fuel spray apparatus.
ii. B5 and B10 were used as the tested fuel for fuel spray deposition investigation.
iii. Fuel injection pump was set at constant speed of 1450 rpm which is corresponding to constant engine speed.
iv. Hot surface temperature was set at 300 °C corresponding to the wall surface temperature that is before the MEP temperature of diesel fuel **[17]**.

CHAPTER 2

LITERATURE REVIEW

2.1 THE EFFECT OF BIO-DIESEL FUEL PROPERTIES

Through the transesterification process, bio-diesel fuel had experienced some changes to its properties such as high density, high viscosity, high CN, lower heat content and etc, as compared to conventional diesel fuel. Thus, this difference in fuel properties will prone to have several impacts on engine operation as well as to the environment. Figure 2.1 below shows the general impact of bio-diesel as compared to diesel fuels.

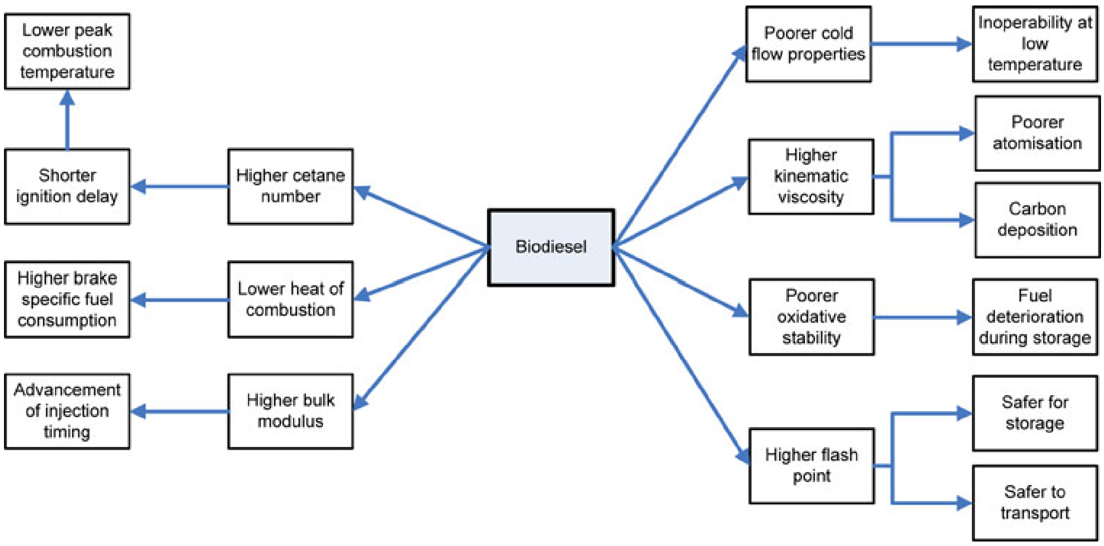

Figure 2.1 Bio-diesel fuel properties and their associated impact on engine operation, storage and transportation as compared to fossil diesel **[18]**

2.1.1 Viscosity

Viscosity of the blended bio-diesel plays major role in operation of CI engine. It is an important factor in predicting the performance of potential alternatives diesel fuel sources **[3]**. This is because minimum amount of viscosity from fuel is needed due to possible of power loss caused by injection pump and injector leakage inside engine. However, higher viscosity of fuels will cause poor combustion rate, due to poor fuel injection atomization **[16]** that leads to deposit formation and high fuel spray penetration (SP) inside cylinder. This in turn will causing engine oil diluted with fuel itself that changing the engine oil properties **[6]**.

Even though high fuel SP properties cause problems as above, it is found that this properties leads to enhancing of power and torque produced onto the engine by some researchers **[6, 7]**. Meanwhile, the higher viscosity and surface tension of bio-diesel than diesel fuel prevent sufficient breaking of the bio-diesel during fuel injection process.

However, according to Aydin and Bayindir **[19]**, they reported that engine torque was decreased when percentage of blends in CSOME (cottonseed oil methyl ester) increased due to higher viscosity and lower heating value of CSOME. This in turn raise up the probability of different feedstock has different properties throughout percentages of bio-diesel blended.

High viscosity properties from vegetable oils and animal fats tends to cause engine problems when used directly in common diesel engines **[20-23]**, if the oils and fats are transesterified using short-chain alcohols, the produced monoesters will have viscosities that are almost identical to petroleum-based diesel fuel **[24]**. These monoesters have come to be known as bio-diesel.

Tesfa *et al*. **[4]** studies the effect of temperature on density and viscosity on three types of bio-diesel fuel – corn oil based, rapeseed oil and waste oil based for various blended percentage. Figure 2.2 below summarize his findings of relationship between different feedstock and bio-diesel blended.