EFFECT OF START INJECTION TOWARD COMBUSTION, PERFORMANCES AND EMISION CHARACTERISTIC OF B20 BIODIESEL FUEL.

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ABSTRACT

The utilization of the palm oil-based fuel in biodiesel fuel as alternative fuel for diesel engine has been implemented in Malaysia. However, the utilization of biodiesel is problematic because the low output power is due to incomplete combustion and incorrect vaporization characteristic. In this research, a small compression ignition engine with 320 cc four strokes direct injection has been used to carry out to characterize the combustion of biodiesel fuel. The performance and exhaust emission have been tested with blended B10 biodiesel (10% POME and 90% pure diesel) and compared with B20 biodiesel (20% POME and 80% pure diesel). The engine was tested under full load steady-state conditions at 1800rpm to 3400rpm with variable start of injection strategy (SOI). Experimental performance measurements including exhaust emissions, cylinder pressure, heat release rate, and ignition delay were conducted. As a result, the use of B20 fuel showed a reduction on engine performances; BT (0.3%), BTE (1.44%), increase of BSFC (up to 3.75%) in comparison with B10 fuels at 2400rpm engine speed. Advancing 1°CA BTDC of SOI strategy in B20 fuel is recommended, where observed an improvement of approximately 3.32% (BTE), 3.23% (BSFC) has been recorded. However, advancing the SOI in B20 fuel increases the Rate of Heat Release (ROHR). The in-cylinder pressure value is also reduced with rise of ROPR. The experimental results prove that the start of injection (SOI) strategy of the fuel has an effect on performance and emission where by advancing SOI by 1°CA bTDC improved 3.3% of BTE. Meanwhile, BSFC is reduced by 3.2% with advancing SOI by 1°CA bTDC. The NO_X emission was decreased by 35.67% (approximately 10.21 g/kWh) with advancing SOI by 1°CA bTDC compared to the default SOI which is at 14°CA bTDC. Therefore, advancing the SOI has the potential to improve the engine performances compared to B10 fuels.

ABSTRAK

Penggunaan bahan api berasaskan minyak kelapa sawit biodiesel sebagai bahan api alternatif untuk enjin diesel telah dilaksanakan di Malaysia. Walau bagaimanapun, penggunaan biodiesel adalah bermasalah kerana hasil kuasa yang rendah disebabkan oleh pembakaran yang tidak lengkap dan ciri pengewapan yang salah ketika penggunaan bahan api biodiesel B20. Dalam kajian ini, enjin pencucuhan mampatan kecil dengan 0.320 liter empat strok suntikan langsung telah digunakan untuk menjalankan pencirian pembakaran bahan api biodiesel. Pelepasan gas ekzos telah diuji dengan biodiesel B10 iaitu campuran (10% POME dan 90% diesel) dan berbanding dengan B20 biodiesel (20% POME dan diesel 80% diesel). Enjin tersebut diuji dalam kondisi pendikit bukaan penuh berdasarkan 1800rpm hingga 3400rpm. Pengukuran prestasi eksperimen, pelepasan ekzos, tekanan silinder, kadar pelepasan haba, dan kelewatan pencucuhan dilakukan dari segi permulaan suntikan pada kelajuan enjin tersebut. Dalam ujian enjin ini, apabila B10 digantikan dengan bahan api biodiesel B20 dalam enjin, hasilnya mengesahkan bahawa pelepasan BSFC, CO_2, NO_X meningkat manakala pelepasan HC dan CO berkurang disebabkan sifat bahan api dan ciri-ciri pembakaran biodiesel. Hasilnya menunjukkan bahawa, untuk bahan bakar B20, apabila memajukan SOI, ia akan memberi kesan kepada kelewatan penyalaan yang semakin meningkat dan menyebabkan peningkatan kadar pelepasan haba (ROHR). Selain itu, nilai puncak tekanan silinder menurun dengan kenaikan kadar kenaikan tekanan maksimum (ROPR). Hasil eksperimen membuktikan bahawa memajukan strategi suntikan (SOI) bahan api mempunyai kesan terhadap prestasi dan pelepasan dengan memajukan 1° CA bTDC, BTE akan meningkatkan 3.3%. Sementara itu, dari sudut BSFC menunjukkan pengurangan sebanyak 3.2%. Pelepasan NO_X didapati berkurang sebanyak 35.67% iaitu 10.21 g/kWh berbanding dengan SOI pada 14° CA bTDC. Oleh itu, memajukan SOI berpotensi untuk meningkatkan prestasi enjin berbanding dengan bahan api B10.

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ABBREVIATIONS AND NOMENCLATURES

%	-	Percent
°C	-	Degree celsius
Au	-	Absorbances units
cm	-	Centimeter
cP	-	centipoise
cSt	-	Centistokes
g	-	Gram
J	-	Joule
kg	-	Kilogram
kW	-	Kilowatt
L	-	Liter
m	-	Meter
ml	-	Mililiter
MPa	-	Mega pascal
Nm	-	Newton-metre
p	-	Density
ppm	-	parts per million
rpm	-	Revolutions per minute
s	-	Second
A20	-	20 percent of annona methyl ester
AFR	-	Air-fuel ratio
ASTM	-	American society for testing and materials
ATDC	-	After top dead center
B05	-	5 percent of biodiesel
B07	-	7 percent of biodiesel
B10	-	10 percent of biodiesel
B100	-	100 percent biodiesel
B20	-	20 percent of biodiesel
BSFC	-	Brake specific fuel consumption
BTDC	-	Before top dead center
BTE	-	Brake thermal efficiency
CA	-	Crank angle
CARB	-	California air resources board
CBWD10	-	10 percent of carbon black of recycled waste tire
CIME	-	Calophyllum inophyllum methyl ester
CN	-	cetane number

CO	-	Carbon monoxide
CO_2	-	Carbon dioxide
DAQ	-	Data acquisition
DC	-	Direct current
EPA	-	Environmental protection agency
FTIR	-	Fourier-transform infrared spectroscopy
GDP	-	Gross domestic product
H_2O	-	Water
HC	-	Hydrocarbon
HCV	-	Higher calorific value
HHV	-	Higher heating value
ID	-	Ignition delay
LHV	-	Lower heating value
MS	-	Malaysian standard
MSDS	-	Material safety data sheet
NBP	-	National biofuel policy
NI	-	National instrument
NO	-	Nitric oxide
NO_2	-	Nitrogen dioxide
NO_X	-	Nitrogen oxide
O_2	-	Oxygen
POME	-	Palm oil methyl ester
RMS	-	Root mean square
ROHR	-	Rate of heat release
ROPR	-	Rate of pressure rise
RPM	-	Engine speed
SAE	-	Society of automotive engineers
SOI	-	Start of injection

CHAPTER 1

INTRODUCTION

1.1 Background of study

Over a century ago, the compression ignition engine was introduced by Dr. Rudolph Diesel, which was at that time occupied as German inventor and mechanical engineer. The diesel fuel was used as power source of the compression ignition engine. Since then, there have been numerous developments and research related to the compression ignition engine. The research covered the design of the engine to alternative and renewable fuel for improving the technology and knowledge of CI engine. The research on alternative fuel has become popular since the oil crisis that happened up to 2018 as shown in Figure 1.1 to decrease dependency on non-renewable fuel such as diesel fuel [1]. Many researchers have discovered that vegetable oil has the potential to replace diesel fuel [2].

Alternative fuel based on vegetable oil, such as palm oil, rapeseed, cottonseed, and sunflower, have the potential as diesel fuel replacement. Vegetable fuel as substitution fuel has already been used in transportation since the second World War. Transportation based on diesel fuel is one of the contributions of black carbon and specific ozone precursors. The regulation of the emission of an automotive and commercial vehicle has been projected up to 2020. The Environmental Protection Agency (EPA) reported excessive ozone level, then the California Air Resources Board (CARB) is seeking to reduce the emission, which is Nitrogen Oxide (NO_X) output by 80%. California has targeted energy production of 60% of renewable by 2030, and 100% of renewable by 2045 [3].

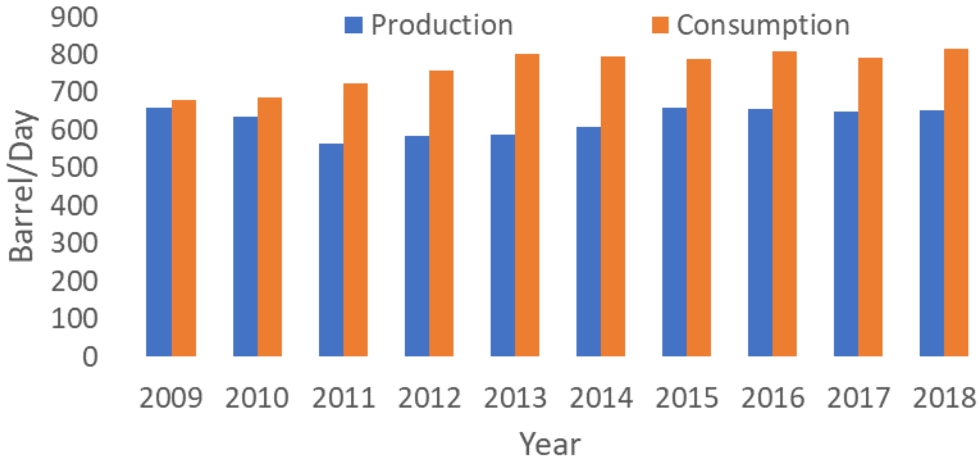

Figure 1.1 Statistic Crude oil production and consumption in Malaysa [1]

From Figure 1.2, Malaysia is one of the most vegetable palm oil production which is 36 percent production at 2019 compared to others vegetable oil production sector. This rich of the vegetable oil supply open the eye of government to looking forward in term of using this converted the palm oil to become Fatty acid methyl ester also known as FAME.

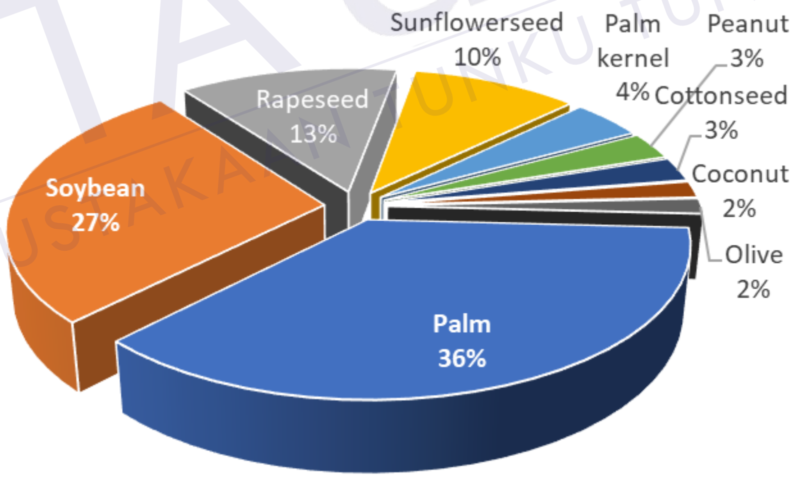

Figure 1.2 Malaysia production vegetable oil and fat in 2019 [2]

Renewable fuel has the potential to reduce emissions from diesel engines. In a common diesel engine, biodiesel can be one of the most polluting alternative fuels relative to prevalent diesel fuel, clean, and less pollutant. Biodiesel is derived from natural oil extracted from renewable sources, and it meets the standard physical properties of biodiesel fuel blend stock (B100) for middle distillate fuels from

ASTM 6751. The standard physical properties of ASTM 6751 include the calorific value, kinematic value, flashpoint, density, cetane number, and others [4].

From the expected the incremental local palm oil demand from the rollout for B20 will be more impactful at 292,000 tonnes in 2021 and 224,000 tonnes in 2022 (or 1.5% of 2020F CPO output from Malaysia). Biodiesel-based palm oil also has the potential to be used in compression ignition engines as substitution fuel without modifying the design of conventional engine geometry. Therefore, the transition from diesel fuel to biodiesel fuel is suitable and sustainable.

1.2 Problem statement

The reserve of crude oil in Malaysia has become more intense. The source of energy is expected to contribute to the significant impact, especially in the commercial energy sector, for example, transportation and power generation. Malaysia is already successful as a pioneer palm biofuel producer since comprehensive palm biofuel program was introduced in 1892. In 2019, it was estimated that total crude palm oil (CPO) feedstock for biodiesel in Malaysia would amount up to 1.5 billion liters, a slight increase compared to the previous year. The Government of Malaysia (GOM) announced its National Biofuel Policy in 2006 to cut down the need on fossil fuels and to help sustain the palm oil (CPO) industry. Although the majority of domestically produced biodiesel is spent by the transportation sector, GOM is also intending to use it in the industrial sector, primarily to heat boilers and generate electricity. Therefore, Malaysia is looking forward to the next level program which used up to 20% of Palm Oil Methyl Ester (POME) in blended biodiesel in the same sector as mentioned in the National Biofuel Policy 2006 which is right now in 2019 malaysia has been implemented B10 in the all sector.

The B20 biodiesel consists of blended 20% of biodiesel and 80% of petroleum diesel. However, the utilization of biodiesel is problematic due to higher viscosity properties compared to diesel fuel, and less calorific which causes less output of power. The low output power due to incomplete combustion and incorrect vaporization characteristic is the main problem of B20 biodiesel fuel usage. In terms of huge challenge of high efficiency and clean combustion of internal combustion engine, all kinds of advanced combustion methods emerged.

The combustion, emission and performance characteristics of CI engine are directly affected by several factors including Start of Injection (SOI) timing, Fuel Injection Pressure (FIP), fuel quantity injection, number of injection, combustion chamber design, number of nozzles, and spray pattern. However, some of these parameters also affect engine power output indirectly, and heat transfer is one of them. Heat transfer is closely related to difference in cylinder phenomenon, namely flame quenching due to cold cylinder walls, and knocking due to excessive Rate of Pressure Rise (ROPR). Heat transfer also affects charge and wall surface temperatures, which have important influence on the formation of pollutants such as Carbon Monoxide (CO), Carbon Dioxide (CO_2), Hydrocarbons (HC), and Nitrogen Oxides (NO_X) [5]. Radiative heat transfer is mainly governed by the quantity of emission produced during combustion, which is significantly affected by SOI timings. Consequently, the B20 biodiesel fuel is tested in single cylinder diesel engine in order to examine the performance of the engine, and to identify the capability of B20 in the compression ignition engine.

1.3 Research questions

i. What is the impact of substituting B10 with B20 biodiesel fuel on engine performances and emissions?
ii. What is the correlation of experiments between SOI strategies fueled with B20 biodiesel?
iii. Fueled with B20 biodiesel, which SOI strategies improve the engine performance’s efficiency and emission?

1.4 Objectives

This study's objectives are:

i. To compare substitution of B10 to B20 fuel in terms of engine performances and exhaust emission of biodiesel fuel in CI engine.
ii. To analyze the effect of SOI strategy on CI engine fueled with B20 biodiesel fuel.
iii. To evaluate the combustion characteristics of biodiesel B20 using SOI in CI engine in terms of in-cylinder pressure, rate of heat release, rate of pressure rise, and ignition delay.

1.5 Scope of research

The scope of this research is as follows:

i. The single cylinder CI engine with 0.320 liters is used as test engine.
ii. The B10 biodiesel fuel used in this research is Petron turbo diesel.
iii. The B20 biodiesel fuel is produced by blending 10% of B100 and 90% of B10 fuel.
iv. The process of blending B20 has been executed according to the EN16709 standard.
v. The comparisons between B20 and B10 in terms of engine performances, Brake Torque (BT), Brake Specific Fuel Consumption (BSFC), Brake Thermal Efficiency (BTE) are measured.
vi. The engine exhaust emissions focusing on Carbon Monoxide (CO), Carbon Dioxide (CO_2), Hydrocarbon (HC), and Nitrogen Oxide (NO_X), are measured.
vii. The SOI strategies of the fuel are focused at seven different crank angles (9°, 11°, 13°, 14°,15°,16°, and 17° CA BTDC), which are 9° CA BTDC to 17° CA BTDC with increment of 2° CA.
viii. The SOI range for B20 fuel is based on in-cylinder pressure, heat release rate, rate of pressure rise, and ignition delay.

1.6 Significance of the research

This research explores the capabilities of B20 biodiesel fuel in the CI engine of performance and emission compared to B10 biodiesel fuel. This research also relates to indirect research, which, as a portion of the National Biofuel Policy (NBP) 2006 which will enhance the nation's wealth by decreasing reliance on depleting fossil fuels. Upon full implementation, the B20 in transportation and industrial are estimated to soak up around 1.3 million tonnes of palm oil per annum. This has indefinitely stifled further growth of palm biodiesel as the high prices and lack of a sizeable market for biofuel has stunted any economic effects that could be observed. It is vital for the biodiesel sector to grow so that corporations and farmers are incentivized by the markets to divert more of the quota from palm oil production towards biofuel, giving a good reason for its use. Other than that, the use of biofuel will reduce fossil-fuel use, reduce sulfur dioxide, carbon monoxide, and particulates to a minimum, and reduce the emission of greenhouse gases. Last but not least, enhanced use of biofuels will improve environmental performance in support with the National Transportation Policy 2019-2030, which is adoption of cleaner fuel such as biodiesel, and achieves 45% reduction of greenhouse gas emission intensity of Gross Domestic Product (GDP) by 2030 across all sectors. To support this, it has been recognized that the characteristics of the injection strategy are the most important factors in influencing emissions and performance of CI engines. In fact, the most notable advancements in CI engines result directly from superior fuel injection system strategy.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The present condition of fossil engines is very critical, and continuous increase in supply of these fuels are urgently needed to find the appropriate solution. Due to enormous number of automobiles in distinct ways of existence, the transportation sector is the leading consuming group. Since 2010, the use of diesel fuel has been the most influential in distinct applications as a result of extensive use of diesel engine.

Awareness towards global warming prevention is being focused solely on small hydrocarbon diesel engine technique as a fossil fuel conversion product. The only way of reducing the usage of the fossil fuels, however, is by increasing the use of renewable resources. In March 2006, the Ministry of Plant Industries and its agencies in Malaysia launched the National Biofuel Policy (NBP). The NBP is focusing on mixing palm oil and petroleum petrol as sustainable fuel. The palm petroleum products can also be converted to biodiesel (methyl esters) [6].

In order to minimize environmental degradation and conserve energy and natural resources, the Malaysian National Green Technology Policy was initiated in July 2009. The policy's objective is to cut carbon emissions equal by 40% by 2020. As of 2010, the government of Malaysia states that 5% of palm oil processed with diesel fuel is the country's determination to generate new demand for 500,000 tons of palm oil, and 10 million diesel per year in national consumption. There is a new demand for palm oil in Malaysia because Malaysia will gain profit from creating green economies to use palm petroleum as a fuel alternative both domestically and internationally, as the world's biggest manufacturer and exporter of palm oil. The use of palm oil biofuel as a renewable resource has a significant purpose in achieving the

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