Effect of Different Biodiesel Blends on Engine Performance, Emissions and Combustion Characteristics under Various Engine Torques and Speeds Condition

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Effect of Different Biodiesel Blends on Engine Performance, Emissions and Combustion Characteristics under Various Engine Torques and Speeds Condition

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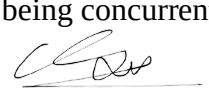
Signed:  …….....…… (CHOW HONG MAN)

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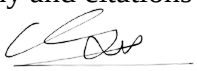
Signed:  …….....…… (CHOW HONG MAN)

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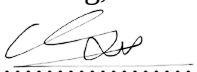
Signed:  …….....…… (CHOW HONG MAN)

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATION

Abbreviation	**Definition**
ATDC	After Top Dead Center
BTDC	Before Top Dead Center
CA	Crank Angle
CN	Cetane Number
CO	Carbon Monoxide
CRDI	Common Rail Direct Injection
EGR	Exhaust Gas Recirculation
HC	HydroCarbon
HCN	Cyanhydric Acid
HRR	Heat Release Rate
IT	Injection Timing
IP	Injection Pressure
IMEP	Indicated Mean Effective Pressure
N_2O	Nitrous Dioxide
O	Oxygen Atom
OH	Hydroxide
PM	Particulate Matter
PAH	Polycyclic Aromatic Hydrocarbons
UHC	Unburned Hydrocarbon
UHV	Upper Heating Value
DOE	Design of Expert Software

Kesan Campuran Biodiesel yang Berbeza ke atas Prestasi Enjin, Pelepasan dan Ciri Pembakaran di bawah Pelbagai Tork Enjin dan Kelajuan

ABSTRAK

Latar belakang eksperimen ialah untuk mencari penyelesaian untuk menangani isu kekurangan tenaga dengan menggunakan bahan api fosil yang boleh diperbaharui sebagai sumber tenaga alternatif untuk enjin diesel. Bio-bahan api ialah pilihan bahan api sejak sedekad lalu sebagai bahan yang boleh diperbaharui dan biodegradasi. Motivasi kerajaan untuk menggalakkan penggunaan Bio-bahan api dengan campuran diesel untuk penambahbaikan alam sekitar tanpa menjejaskan prestasi enjin. Kebanyakan penyelidik menjalankan penyelidikan menggunakan Bio-bahan api dalam enjin diesel. Eksperimen dijalankan dengan menggunakan campuran biodiesel (B0, B20, B40, B60, B80 dan B100), pada pelbagai beban enjin seperti 25%, 50%, 75% dan 100% dan kelajuan enjin diesel, 2350rpm, 3100rpm dan 3850rpm untuk menguji prestasi dan pelepasan enjin diesel. Hasil prestasi ialah Kuasa, Kecekapan Terma Brek (BTE), Penggunaan Bahan Api Tentu Brek (BSFC), dan pelepasan seperti Nitrogen Oksida (NOx) dan Asap. Kesemua data biodiesel yang diuji dan diperoleh dengan menggunakan perisian Labview dan DeweSoft, simulasi dijalankan dengan menggunakan perisian RK Diesel untuk mengesahkan ketepatan data, dan pemilihan nisbah campuran biodiesel, kelajuan enjin dan beban enjin, untuk mencari maksimum BTE dan BSFC dengan pelepasan NOx dan asap minimum yang boleh dicapai dijalankan dengan mengakses perisian Design-Expert. Keputusan eksperimen menunjukkan bahawa biodiesel B60, kelajuan 2070rpm, Beban 55% adalah pilihan optimum untuk memaksimumkan BSFC, BTE dan kuasa enjin, dengan meminimumkan prestasi pelepasan enjin.

Effect of Different Biodiesel Blends on Engine Performance, Emissions and Combustion Characteristics under Various Engine Torques and Speeds Condition

ABSTRACT

The experimental background is to determine a solution for combating the energy shortage issue using renewable fossil fuel to alternative energy sources in diesel engine. Biofuels is the choice of renewable fuels since the past decade as renewable and biodegradable fuels. Globally, the urge and support of government to promote the usage of biofuels mixing with diesel blend for the betterment of environment without jeopardizing the engine performance. Most of the researchers believe fossil fuels is a source of clean energy when mixed with biofuel, and they have conducted research of utilizing biofuels in diesel engine. The experiment is conducted by utilizing biodiesel-diesel blend (B0, B20, B40, B60, B80 and B100), at various engine load such as 25%, 50%, 75% and 100% and engine speed of idle, 2350rpm, 3100rpm and 3850rpm to test the performance and emissions of a diesel engine. The performance results are the Power, Brake Thermal Efficiency (BTE), Brake Specific Fuel Consumption (BSFC), and emissions such as Nitrogen Oxide (NOx) and Soot. For all the tested biodiesel data is obtained by using the Labview and DeweSoft software, simulation is conducted by using the RK Diesel software to verify the data accuracy, and the choosing of best biodiesel mixing ratio, engine speed and engine load, to find the maximum BTE and BSFC with the minimum achievable emissions of NOx and soot is conducted by accessing the Design-Expert software. The results of the experiments indicate that biodiesel B60, speed of 2070rpm, Load of 55% is the optimum choice to maximize the BSFC, BTE and engine power, with the minimization of the engine emissions performance.

CHAPTER 1: INTRODUCTION

Energy is the capability to perform activities. It is possible to harness the wealth of energy that surrounds us and use it in our everyday lives in a variety of ways. Fossil, renewable, and fissile are all types of energy sources. Non-renewable fossil fuels were created over a long period of time. Based on current world demand, oil will be depleted over the next several decades.

Therefore, most of the researchers have experimented and stated that biodiesel and biodiesel-diesel blends fuel have better engine performance, more eco-friendly and biodegradable. Biodiesel offers advantages such as having higher brake specific fuel consumption (BSFC) levels and lesser emittance of soot levels compared to pure diesel. On the contrary, the biodiesels usage would have side effects like emittance of higher amount of Nitrogen Oxide (NOx). In addition, biodiesel has a lower heating value, a greater density, and a higher fuel consumption than conventional diesel fuels. (Mamuni et al., 2021) Thus, to counteract with these disadvantages, we require more new and advanced approaches to improve the biodiesel emissions in diesel engines, such as different injection strategies.

1.1 Research Background

Fossil fuels provide about 80% of the world's overall energy supply, but technological advancements have sparked a new trend toward alternative energy sources. Also, fossil fuels such as oil are rapidly depleting due to climate change. Thus, there is a necessity to conduct research on the suitability and effect of replacing pure diesel with biodiesel.

Biodiesel is a product from the process of transesterification, which has been chosen as the possible substitute to pure diesels for the future fuel consumption of diesel-engine vehicles. Unlike pure diesel, biodiesel is biodegradable, renewable energy source and nontoxic (Hoang, 2018). Also, Wilmar International Limited in Malaysia is one of the main, refinery, exporter, and supplier of palm oil globally, which has the geographical advantages, low in cost and available for further research on its possibility to replace pure diesel.

Variables such as fuel blend, number of injections, and mass ratios would be investigated on the engine performance, combustion characteristics, and emissions using a common-rail fuel injection system diesel engine with turbocharged intake air supply. Intake air throttled will be used on the engine under test. It has an Electronic Control Unit (ECU) that can control SOI time, injector opening pulse-width (PW), and responds to engine speed and intake air throttle position on the engine bench test. Secondly, in-cylinder pressure transducer. Thirdly, data acquisition system and crank angle encoder. Fourthly, an intake air throttle with throttle position sensor.

The combustion properties and engine performance of various biodiesel-diesel fuel mixes will be tested in the following periods. Testing will focus primarily on the injection strategies and the control of the intake air supply. The expected outcome of this project would be achieved through the study of various parameters such as mass ratio, biodiesel-diesel blend and intake air supply to evaluate the best optimization of engine parameters to minimize the problem of NOx emission and soot formation that leads to betterment of the environment.

1.2 Problem Statement

There are only few studies that investigate and analyze biodiesel blends application in a commercial 4-cylinder engine. Consequently, the primary goal of this research is to assess and optimize diesel engine fuel injection parameters by choosing the best mixing ratio of biodiesel fuel, to improve the problem of NOx emission and soot formation, without compromising BSFC and jeopardizing engine performance. The biodiesel-diesel blend should be tested on more specific range such as B20, B40, B60 and up to each interval of 20 percentage of biofuel to further verify its effect on engine performance and emissions. The ASTM D6751 is our biofuel standard establishes specifications for a biodiesel blend stock, to verify the deviation of engine performance results with other scholars. Furthermore, biodiesel is proved to increase the BTE and reduce the BSFC, as the biofuel percentage increases in the blending ratio, but the effect on engine performance is not the same for all feedstock in second-generation biodiesel, thus palm oil is the source of this experiment to verify, along with the NOx and soot emissions.

1.3 Project Objectives

1. To study the biodiesel and diesel blends effect on engine performance and engine emissions under various engine speed and torque.
2. To simulate the engine performance using RK-Diesel software and analyse the experimental data using Design Expert software.
3. To obtain the best percentage of biodiesel fuel and operating point on engine performance.

1.4 Proposed Solution

A diesel engine's performance and emissions will be compared to those of a pure diesel utilized engine, by using biodiesel-diesel fuel mixes as part of the study's scope. Besides, to reduce the diesel engine emissions of particulate matter and assess the combustion performance of engine with intake air throttle implementation. Also, to evaluate the potential of air intake throttled operation and EGR in diesel engine for the reduction in NOx, particulate matter, and smoke.

In addition, to investigate the optimum ways to reduce particulate matter emission and brake specific fuel consumption.

CHAPTER 2: LITERATURE REVIEW

2.1 Overview of Project

Malaysia is one of the biggest agricultural commodities exporters in the world, the commodities such as palm oil, rubber and others generate more than RM40 billion to Malaysia revenue. Most of the bioresources generated can be utilized for alternative substitute to diesel fuels, due to its renewable and bio-degradable feature.

Regarding the topic of environmental friendliness, several investigational strategies were proposed to limit the emissions of pollutants from diesel engines. The three ways proposed are as follows: improving the operational parameters of the engine design to increase engine combustion efficiency, consequently decreasing fuel consumption and exhaust emissions. The second step is to treat tailpipe (exhaust system) exhaust emissions with catalytic converters or diesel filters. The third is the utilization of alternative energy fuels, such as biodiesel. The following literature review themes are based on the most recent developments.

2.2 Biodiesels versus Traditional Fossil Diesel Usage in Diesel Engines

Biodiesel was considered as a viable option or alternative to the fast depleting of fossil fuels, due to its adoptability. Biofuels are produced through the process of transesterification by utilizing the alcohol with the hydrogen oxide, OH as a catalyst. Besides, the biodiesel is preferable as compared to pure diesels due to its lesser particulate matter and less total hydrocarbon. By mixing biodiesel-blends with diesel, it is experimentally proved that when increase the percentage of biodiesel blend, there is an increase in specific fuel consumption and a reduction in particulate matter and hydrocarbon emissions because biodiesel has a lower heating value. According to research (Mamuni et al., 2021), biodiesel has a poor heating value, a greater density, and a higher fuel consumption., the only drawback is it also emits more amount of nitrogen oxide.

A study from Rakesh Kumar suggested that by using the biodiesel, the experiments show slight improvement in brake power and lower CO and HC emission (R. Kumara et al., 2019). Furthermore, the engine performance measures, such as BTE, increased when tested utilizing papaya seed oil biodiesel and oxygenated additives with diesel blend. (Anwara et al., 2019).

Previous study (Teoh et al., 2020) demonstrated that the utilization of biodiesel (Cocos nucifera) in a diesel engine increases the BTE and BSF consumption of the engine. Anyhow, the study by (Kanth et al., 2020) indicated that by utilizing the biodiesel-diesel blends, it results in lower BTE especially in higher loads. Additionally, utilization of the biodiesel mixing results in the deteriorating of the engine performance and higher

emissions of NOx. But, by adding the biodiesel with hydrogen, it shows an increment of 2% BTE and higher percentage of BSFC under higher load conditions. The research shows the biodiesel blends with enrichment of hydrogen increase the heat release rate and BTE and reduce the fuel consumption. Research done by (Sameh et. al, 2021) indicates that the biodiesel reduces the CO emission by 17%, HC by 39%, exhaust opacity by 48%), with slight change in NOx in comparison to pure diesel fuel.

2.3 Effect of Biofuels on the Engine Performance: Power

The heating value and viscosity have a direct impact on engine power components. Heating value is an evaluation of the energy amount that may be used to perform work. Since biodiesel has a lower heating value, theoretically it would result in lower engine output. Overall, it was considered that as biodiesel exhibits lower heating value, thus it is the primary cause of its power loss. The biodiesel's high viscosity and density characteristics, along with its poor heating value, are the primary causes of its higher fuel consumption also.

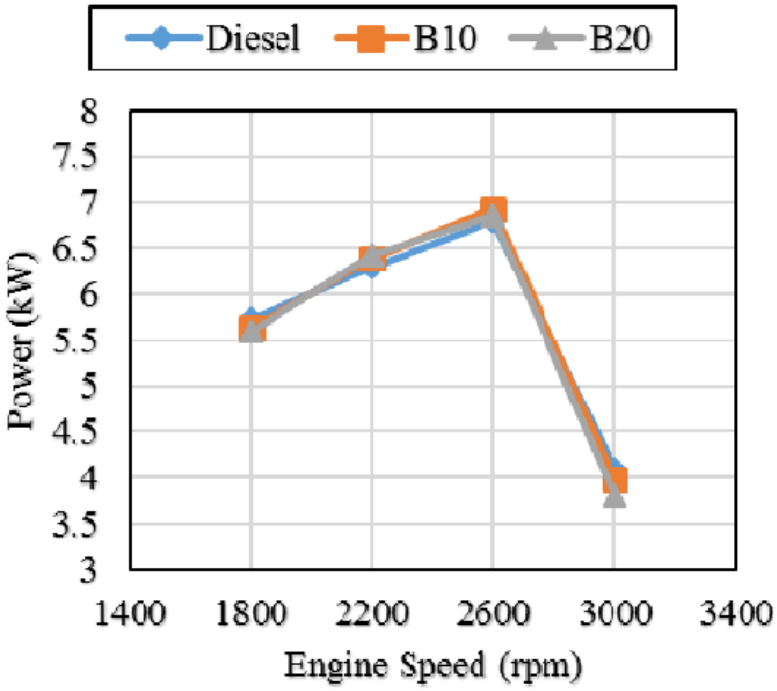

Figure 2.1: Graph of Power(kW) against Engine speed(rpm) by Reza Re, et. al (2016). Effects of biodiesel fuel synthesized from non-edible rapeseed oil on performance and emission variables of diesel engines.

Fig. 2.1 shows the power fluctuations of biodiesel and diesel fuel blends at various engine speeds and full load. At 2600 rpm, B10 produced the most power, while B20 produced the least at 3000 rpm. Output increased steadily with engine speed until 2600 rpm, when frictional force caused a reduction in power. It is an example conducted by researcher Reza Re et al (2016), that by using biodiesel, it is common to incur loss in engine power.

But still, there is still other voice that states that the high lubricity and high viscosity of biodiesel have not been proven to have any significant influence on engine power. Also, the use of biodiesel feedstock has no significant impact on engine power [1].

Most of the researchers achieve a mutual consent that the biodiesel would cause the drop in the engine power, especially B100 which is pure biodiesel, due to the drop in the biodiesel heating value.

Researchers tested the engine performance characteristics of pure diesel and pure biodiesel, and varying percentages of biodiesel (B10, B30 and B50) combined with pure diesel in a single-cylinder, four-stroke, direct-injection diesel engine with varied load conditions. Increasing the percentage of biodiesel in the blend reduced the engine's power output. Power production at the lowest and highest engine speeds were reduced when biodiesel to diesel ratios were increased (1800 and 3000 rpm). This is due to the biodiesel has a lower energy density than diesel at the same volume [2].

The engine speed, engine load, and the percentage of biodiesel–diesel mixes blends exerted their impact on the engine's output power [3]. According to research, when biodiesel content in a fuel mix grows along with engine torque, the engine power drops.

Similar to the influence of engine speed on power, aside from rare instances, other researchers discovered that the power loss was lower than predicted in contrast to diesel because of power recovery.

For the rare instances, there is a reason for explanation, which is the fuel is pumped into cylinders on a volumetric basis in diesel engines. As the biodiesel blend is denser than diesel fuel, thus when biodiesel blends pumped into an engine, biodiesel has a greater mass flow rate and produces more power [4].

2.4 Effect of Biofuels on the Engine Performance: Brake Thermal Efficiency

The ratio of braking power obtained in the crankshaft to the fuel power provided to the engine is known as the brake thermal efficiency.

Depending on the type of biodiesel utilized and its blending ratio with diesel, the range of exhaust emissions and engine performance factors are varied. When biodiesel-diesel mixtures are utilized, the BTE (brake thermal efficiency) is reduced.

According to the researcher the BTE for a biodiesel–diesel blend reduces little when compared to diesel [5]. Researcher tested the effects of varying percentages of biodiesel on the engine's performance and emissions. Increasing the percentage of biofuel results in the reduction of the BTE of the engine, according to the researchers. It was discovered that when biodiesel–diesel blends were utilized instead of diesel, the biodiesel–diesel mix reduced the BTE [6].

The BTE was found to be comparable when the biodiesel–diesel combination was used. Biodiesel's reduced BTE has been attributed to its viscosity, cetane index, lower heating value all of which have been observed by researchers [7].

Researcher showed that rubber seed oil blends with diesel had a lower BTE than diesel in contrast to the jatropha and diesel fuel mixtures that were tested. The engine's performance has been enhanced using a variety of biodiesel kinds and mixes. BTE, engine torque (ET), and braking power (BP) are often lower for mixed biodiesel-diesel blend [8].

Numerous studies have shown that all biodiesel fuel blends reduce BTE when compared to pure diesel. Lower heating value, high viscosity and high density induce poor

atomization which are the main drivers of this declining behaviour. On the other hand, a few studies suggest that biodiesel fuel has a greater heating value and a negligible viscosity at high injection pressures.

2.5 Effect of Biofuels on the Engine Performance: Brake Specific Fuel Consumption

The engine's total fuel consumption per brake power unit it generates is known as the brake specific fuel consumption (BSFC). When evaluating the impact of fuels on engine performance characteristics, this is a key metric. BSFC for microalgal oil and microalgal oil methyl ester exceeds diesel at all loading circumstances when the engine was fed with these fuels. The lower heating value of the test fuel resulted in the higher fuel consumption to maintain a consistent power output, according to the research [9].

It was discovered that adding more biodiesel to a diesel generator that was running on waste frying oil mixes, discovered that the generator used less fuel. The B5 blend had the highest fuel usage (3.10 kg/h) and the B20 mix had the lowest (2.64 kg/h) during the course of the whole test. BSFC of diesel-powered generators also showed the similar tendency, according to the authors [10]. The lower calorific value of oxygenated biodiesel fuel boosted the engine's BSFC because of the fuel's higher oxygen content. Biodiesel from fish oil increased the BSFC of four-stroke DI diesel engines in a linear fashion [11].

It is widely agreed by Sathyamurthy and coworkers that the BSFC increases when biodiesel is used as a fuel in typical CI engines rather than diesel [12]. For instance, Biodiesel percentages of B20 and B100 were shown to boost the BSFC by 4 percent and