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# CHARACTERIZATION OF BIODIESEL FOR USE AS A FUEL IN COMPRESSION IGNITION ENGINE

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## ABSTRACT

Biodiesels are fuels that are made from renewable oils that can usually be used in diesel engines without modification. These fuels have properties similar to fossil diesel oils and have reduced emissions from a cleaner burn due to their higher oxygen content. The present work investigates the performance of three types of biodiesel and diesel fuels in a Mitsubishi 4D68 4 in-line multi cylinder compression ignition (CI) engine using transient test cycle. The test results that will obtain are brake power, specific fuel consumption (SFC), brake thermal efficiency and exhaust emissions. An instrumentation system also will be developed for the engine testing cell and controlled from the control room. Biodiesel was also tested against diesel fuel in Exhaust Gas Recirculation (EGR) system. Thus it is possible that biodiesel fuels may work more effectively than fossil diesel in certain applications.

**Keywords:** Biodiesel, CI engine, transient, Instrumentation, EGR

## INTRODUCTION

Biodiesel, is the generic terms for all types of Fatty Acid Methyl Ester (FAME) as one among other organic renewable alternative fuel that can be used directly in any conventional diesel engine without modification. They are transesterified vegetable oils that have been adapted to the properties of fossilized diesel fuel and considered to be superior since they have a higher energetic yield been combusted in the diesel engine (Adams 1983) . Current compression ignition (diesel) engines are able to operate upon a wide range of fuels due to its specific characteristic which is internal combustion under a variety of operating conditions. In a world of resources, it seems prudence to focus upon fuels which are potentially efficient and renewable, like bio-fuels. Besides this advantage in fuel flexibility, compared to those of spark ignition (petrol) engine, diesel engine can offer better engine durability, higher thermal



efficiency and more economical fuel consumption. Through centuries, diesel engine was used in many sectors such as in transportation and industries. Diesel engine is used in heavy industries, automotives, ships, locomotive, transportation such as truck and buses, and also farm equipments such as lawnmowers and tractors. The latter relates to fuel economy savings that can potentially produce less carbon dioxide (CO<sub>2</sub>) emission. Diesel engines are therefore, part of a long term solution to global warming

Diesel engine use fossilized fuel in its combustion process. However it is estimated that the fossil fuel supply will decrease in the future. This happens due to maximum production of the fuel which cause fuel reserve been decrease drastically to a

minimum level. Eventually it leads to demand exceed supply and finally increase the fossil fuel price. Beside that fossil fuel use also leads to environmental problems such as toxic emission and releasing of harmful particles. This particulate matter (PM) generated from the unburned hydrocarbon which forms black soot. It is found that the particulates can result cancer, respiratory diseases and others that can affect the health of human (Beggs 2001). In order to solve those problems, many researchers trying to discover new technology such as solar cars, hybrid cars, hydrogen fuel cell cars and such on to replace most of the internal combustion engine including diesel engine. Even though many successful findings been recorded years ago, but still expensive in terms of cost, impractical and need better research to improvise it.

The most preferred solution is using the renewable alternative fuels that can support the diesel engine. Those alternative fuels are not been produced by the fossil fuel distillation but been extracted through a chemical process called transesterification process to produce methyl ester or ethyl ester that fueled the diesel engine without any modification. Those fuel properties similar to diesel fuel but produce less emission and same or higher performance than the diesel fuel itself.

### ***Project Overview***

The use of renewable alternative fuels to replace the conventional fossil fuels and its potential was well known and been studied many years in other continents such as Europe and America. This been proved by the certified significant results from the many research that been conducted and the regulations and standards enforced by various agencies. However in Malaysia, alternative fuel usage is still doubtful stage due to lack support from the public and also the government agencies. Many people are uncertain of the performance generated by the diesel engine using the alternative fuels. This research determines the performance and emission generated by four stroke diesel engine to gather more technical data that useful for the research field enhancing the use of alternative fuels rapidly. The alternative fuels used in this research are Palm Oil Methyl ester B100 (100% palm oil) that been produced by three method of transesterification process and also conventional diesel fuel provided by Petronas. The engine performance test will be performed using the alternative fuels and



conventional diesel fuel in order to obtain engine performance characteristics and also exhaust emission based on transient mode of cycles. Among the characteristics considered are brake power, maximum torque, engine speed, fuel consumption, performance index, thermal efficiency, torque and crank angle. The data obtained throughout the research will be converted to graphical form in order to study the patterns of torque-power curve and determine the engine performance with different fuels. Besides that, level of emission and also its content been compared with different fuels to determine which alternative fuels has better and environmental friendly.

### Problem Statement

The purpose of this research is to determine engine performance and level of exhaust emission generated by palm oil methyl ester and conventional diesel from Petronas. Several objectives are aimed in order to achieve the research goals and performing the research smoothly. Among the objectives are:-

- a. To commission an engine test rig fully equipped with the instrumentation system.
- b. To determine engine performance and exhaust gas emissions during combustion of diesel and biodiesel fuel with transient mode of cycles.

This research work is initiated by the recent interest in the use of biodiesel as a part-substitute for diesel fuel. There is a need to extend research on engine performance and emission effects of such fuels in order to obtain the data required by motor industry. The research was performed on the engine test rig which comprised of a Mitsubishi 4D68 SOHC Direct Injection 2.0L diesel engine coupled on ECB eddy current dynamometer. The test engine is equipped with cylinder pressure data acquisition equipment, exhaust gas emission measurement devices, an exhaust gas extraction system, an engine cooling system (turbocharger intercooler, engine cooler, and fuel cooler), fuel/air-flow measuring instruments, and an engine management system (EMS). The engine dynamometer set includes: the brake cooling systems (both air and water), measuring devices, and load control systems (mechanical and electrical). Furthermore, it requires a ventilation system in the test cell. The Mitsubishi diesel engine was tested at different engine operating condition points by using the aforementioned of biodiesel fuels with conventional diesel fuel in order to determine the quantitative impact on engine performance and emissions. The tests were based on the engine dynamometer over a sequence of steady-state modes and were operated for the prescribed time in each point for specific speeds/loads. Emissions were measured during each mode and averaged over the cycle using a set of weighting factors. Regulated emissions: HC, NO<sub>x</sub>, CO, and smoke, as well as other major gases: carbon dioxide (CO<sub>2</sub>) and oxygen (O<sub>2</sub>) were measured. Several engine combustion performance

indicators have been determined such as: cylinder pressure trace, heat release pattern, fuel consumption, and thermal efficiency.

## MATERIALS AND METHODS

### Engine specifications

The apparatus used for conducting the emission testing and analysis of the engine exhaust sample is located in Automotive Lab, Universiti Malaysia Pahang at Pekan. The first thing to start with was an engine and a dynamometer set up, the automotive engineering lab already consisted of a 150 KW eddy current dynamometer model ECB which was previously being used for engine testing as shown in Figure 1. The distributor pump in the Mitsubishi 4D68 engine was equipped with a centrifugally controlled timing device for correction of start of delivery. Moreover, the distributor pump was also equipped with a boost control device, a boost pressure actuated diaphragm mechanism that adjusts the maximum fuel delivery from the pumping element relative to the boost pressure. The delivery of fuel to the cylinders in a distributor pump always ends at the same stroke travelling independent of fuel quantity injected (Bosch 1996). The power unit was self contained in itself and came along with all the necessary components like vibration dampers, engine control unit and exhaust muffler mounted already. The specifications of the test engine are shown in Table 1.



Figure 1: Mitsubishi 4D68 SOHC 2.0 L Diesel Engine Testing rig



Performance of any fuel can be judged by the power and torque output that it can generate. Biodiesel has a higher cetane number than conventional diesel, but has a lower energy content per volume. Because of the lower energy content, using biodiesel without any change in the fuel injection system would result in a slight loss of engine power. Numerous studies have been undertaken to test these theoretical results. It should be noted that power and torque is difficult, if not impossible, to accurately measure in- use; therefore, power testing has occurred in controlled laboratory environments with specific duty cycles that are designed to stress engines. For example, the 200-hour Engine Manufacturers Association (EMA) test includes significant time where the tested engine is operating at full throttle (Idaho May 1996).

Table 1: Specifications for a Mitsubishi 4D68 Diesel engine Model 1995

Descriptions	Specifications
Number of cylinders	4 in-line
Combustion chamber	Swirl chamber
Total displacement cm	1.998 cc (121.925 cu in)
Cylinder bore mm x Piston stroke mm	82.7 x 93
Bore/stroke ratio	0.89
Compression ratio	22.4:1
Maximum Power	(JIS) 88.2 PS (87 bhp) (64.9 kW) @ 4500 rpm Specific output 43.5 bhp/litre 0.71 bhp/cu in
Maximum Torque	(JIS) 177.0 Nm (131ft.lb) (18 kgm) @ 2500 rpm Bmep 1113.2 kPa (161.5 psi) Specific Torque: 88.59 Nm/ litre

### Test Cycles and Experimental Procedure

In Europe, USA and Japan there is an obligation for manufacturers to certify new engine models to emissions performance standards. In order to control level of atmospheric pollution caused by vehicle engine emissions, the international legislation has established over the years a series of tests to evaluate the potential capability to pollute of different types of engines in order to impose restrictions to the



commercialization of high polluting engines. These tests have been designed with the purpose of simulating real engine operating conditions by the performance of steady and transient test cycles. Tests cycles established by legislation specify the characteristics of the whole measurement system necessary to perform the test, including measurement configuration, devices and procedure (Arregle J. 2005). The required specifications differ in its conditions from steady to transient tests. Non-road mobile equipment (non-road diesel engines) is currently tested according to an eight-mode steady-state test cycle, ISO 8178 (ISO 1996). Another standard widely used is ECE Regulation No. 49 (ECE 2000) which includes 13 steady-state test modes. In a steady-state test cycle, emissions are measured at a sequence of several modes of fixed engine speed and torque. Average emission values for the whole cycle are obtained by summarising the measured emissions at the individual modes, according to different weighting factors (Hansson 2003). The procedure of the standards is one reason why most efforts in engine development recently have been directed towards improving the characteristics at static load conditions.

Transients in engine speed and torque, i.e. changes in engine speed and torque, occur frequently during the normal operation of non-road vehicles (Adams 1983; Starr M 1999; Ullman T 1999). Fuel consumption and emissions of CO<sub>2</sub>, CO, HC and NO<sub>x</sub> were measured according to a 20-mode steady state cycle. The 20-mode steady-state cycle used was based on the 13-mode European ECE Regulation No. 49 test cycle (ECE, 2000) and extended with nine additional modes in order to increase the resolution as shown in Figure 4. The test cycle ECE Regulation No. 49 includes 11 unique engine load conditions, the remaining two modes are repetitions of the low idle mode. The fuel consumption and emissions were measured in accordance with the ISO 8178 regulation (ISO, 1996).

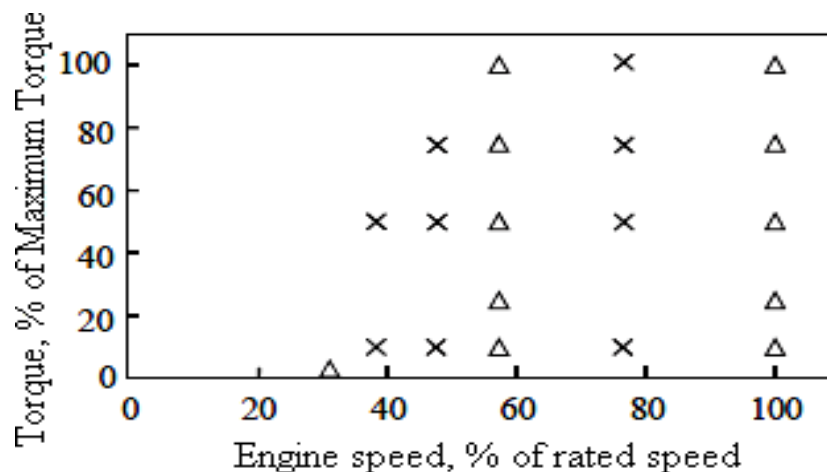


Figure 4: Twenty-mode steady-state test cycle based on ECE Regulation No. 49 ( ) and extended with nine additional modes (x) (Hansson 2003)



## RESULTS AND DISCUSSION

All the tests and data analysis will be performed with different fuels in the Automotive Laboratory, Faculty of Mechanical Engineering, Universiti Malaysia Pahang at Pekan. In the research, there are some expecting results that can be referred from previous study. The test cycle modes will be running based on ECE (2000) 13 modes cycles which using different engine speeds and torques comparing with each fuel in the engine testing. The pattern of the graphs will indicate the performance of the engine using biodiesel and conventional diesel fuel. The correction of emission factor also will be considered to determine the best result for the study. Most of the biodiesel study is using diesel engine without any modification of any parts. Practically the performance of the engines was generally as good as on petroleum diesel. Previous studies also showed the engines were easy to start, with no knocking and smooth running. Most of the previous results showed that the exhaust emissions of the engines were much cleaner with less hydrocarbons, NO<sub>x</sub>, CO<sub>2</sub> and SO<sub>2</sub>; therefore, proven that the fuel was more environmentally-friendly.

### *Brake Power output*

Kalam (2008) found that the biodiesel fuel with additives produced higher brake power over the entire speed range in comparison to other fuels in his studies. It shows that the effect of fuel additive in blended biodiesel fuel influenced the conversion of thermal energy to work or increases the fuel conversion efficiency by improving the fuel ignition and combustion.

### *Specific Fuel Consumption*

Specific fuel consumption is totally depending which type of fuel that been used in the engine testing. Kalam (2008) showed that the blended biodiesel with additives is produced higher fuel conversion compared with other biodiesel fuel at engine speed higher than 3500 rpm. Canakci and Van Gerpen (Canakci 2001) showed that B100 (100% soy biodiesel) had a higher brake specific fuel consumption (BSFC) when compared to fossil diesel. This reflects its lower heating value (about 12% lower than diesel).

### *In Cylinder Pressure*

A research conducted by Spaddacini on autoignition characteristics under controlled conditions revealed that when the boost pressure increase (or pressure drop decrease), the ignition delay decrease, resulted to the higher peak pressure in engine cylinder (Heywood 1988). The ignition delays reduced associated with the reduction in premixing time when the boost pressure increase due to the increase of volumetric efficiency at constant intake oxygen. The ignition delay for RME (Rape seed Methyl



ester) is shorter as compared to ULSD (ultra low sulphur diesel) due to higher bulk modulus of RME which caused an early injection event (Mamat 2009).

### ***Oxides of Nitrogen (Nox) Emission***

According to Heywood (1988), NO<sub>x</sub> that consists of nitric oxide (NO) and nitrogen dioxide (NO<sub>2</sub>) where the nitric oxide is dominants with a small amount of NO<sub>2</sub> is produced from high combustion temperature and related with the individual fuel combustion temperature. The use of additives can help to reduce the combustion temperature by allowing high fuel conversion (Kalam M.A 2008).

### ***Carbon monoxide (CO) Emission***

During the combustion process, CO is formed when the condition of insufficient oxygen to burn all the carbon in the fuel to CO<sub>2</sub>. In eliminating effects of CO emission, a diesel engine will normally uses more oxygen (excessive air) to burn fuel and by theory, the combustion will fully complete.

### ***Hydrocarbon (HC) Emission***

Kalam (2008) also showed that the blended biodiesel fuel with additives produced the lowest HC emission compared with other fuels. The combustion of RME promotes very low unburned hydrocarbon compared to ULSD due to high burning rate estimated by heat release as reported by many researchers on biodiesel (Agarwal 2007). For the safety reason, the palm oil methyl esters did not produce an explosive air/fuel vapour. Instead, they offered enhanced safety with a higher flash point (120°C compared to 60°C of petroleum diesel). The quantity of carbon build-up in the engine nozzles was normal except that the nature of the carbon was different. For the consumer advantage the fuel consumption of palm diesel was comparable to that of petroleum diesel (e.g. 3-4 km litre-1). Disadvantage of using the palm oil methyl esters as fuel attacked low grade plastic and rubber products, such as hoses, seals, etc. and also reacted with the binding material in cement floors.

## **CONCLUSION**

This work contributes to the ongoing research in renewable energies, mainly the use of biodiesel as an alternative or blending additive for commercial petro diesel. In this study the effect of blending biodiesel on emissions and efficiency in a non road diesel engine were tested. The findings were compared to published results from similar experiments. It has to be said that these results are based on stationary diesel engine and hence a correlation between engine performance and emissions with road vehicles cannot be made. Furthermore, no modifications (e.g. injection time alteration, fuel pre- heating system) were made to engine to adjust for the lower viscosity of

biodiesel compare to standard diesel. The quality of the palm oil biodiesel was based on MPOB standard concerning the production and no other biodiesel grades were tested in this study. Comparison also will be made according to the test results between biodiesel fuels and conventional diesel fuel based on the modes of cycle. However these results show a good usefulness for diesel powered generating systems being adjustable for biodiesel and its blend. This can be of particular interest for farmers and other parties with easy and cheap access to biodiesel for the purpose of energy generation by reducing emissions to the environment and increase their carbon footprint. From an economical point of view, the use of biodiesel has been proven in numerous other papers and hence adds to benefits of its use.

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