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Engine Performance and Emissions Analysis using "Envo Diesel" and Coconut Biodiesel Blended Fuel as Alternative Fuels

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***Abstract*—The Environmental concerns and regulations to reduce green house gas emission and fluctuation of fossil fuel price have stimulated research on alternative fuels. Moreover, use of unproductive land to produce vegetable oil which is a potential biodiesel source has opened up a way to reduce oil bill. Biodiesel does not need major modification in engine, even though it causes some engine problems in long term use. This paper presents experimental results that evaluates the performance and exhaust emissions of a diesel engine operated on "Envo Diesel" which consists of 5% palm diesel and 95% ordinary diesel fuel (also termed as P5) and C5 (5% coconut biodiesel and 95% ordinary diesel fuel. Experimental results showed that P5 and C5 reduced brake power compared to diesel fuel by 1.2% and 0.7% respectively. Emissions such as HC, smoke, CO and NO_x concentration were lesser for P5 and C5. The results of this investigation will be used to partial replacement of diesel fuel using low percentage of methyl ester (maximum 5%) obtained from waste vegetable oils.**

Keywords-Envo Diesel; Coconut biodiesel, Performance; Emissions

I. INTRODUCTION

Recently, the use of diesel engines has increased rapidly because of their low fuel consumption and high efficiencies. Nowadays, diesel engines are used in transportation, power plant generation equipment, construction and industrial activities. These wide fields of the usage lead to increase the demand for petroleum fuel which is presently confronted with crises of reservations and concerns about environmental degradation.

The present energy scenario has stimulated active research interest in non-petroleum, renewable, and non-polluting fuels. The world reserves of primary energy and raw materials are, obviously, limited. According to an estimate, the reserves will last for 218 years for coal, 41 years for oil, and 63 years for natural gas, under a business-as-usual scenario [1].

Malaysia is located near the equator, Malaysia's climate is categorized as equatorial, being hot and humid throughout the year. Annual rainfall exceeds 2000mm a year and the average temperature is 27 °C (80.6 °F). Malaysia faces two monsoon winds seasons – the Southwest Monsoon from late May to September, and the Northeast Monsoon from November to March. The Northeast Monsoon brings in more rainfall compared to the Southwest Monsoon [2]. This climate is very suitable to cultivate palm trees as well as palm oil. Currently total palm oil plantation area is 3.33 million hectors which is only 10% of total area [3]. Malaysia currently accounts for 41 % of world palm oil production and 47% of world exports, and therefore also for 11% and 25% of the world's total production and exports of oils and fats. As the biggest producer and exporter of palm oil and palm oil products, Malaysia has an important role to play in fulfilling the growing global need for oils and fats in general [4]. Malaysian government has taken several initiatives to produce palm diesel (palm oil methyl ester). The 10% of total palm oil production is allocated to produce palm diesel. However, more than 30% of land area in Malaysia is under raw forest and not producing fruits or food products. This land could be used for palm oil or coconut oil or Jatropha (non-food) plantations; and it will be beneficial to job creating for workers, increased renewable sources and less environmental pollution. The maximum 5% of biodiesel obtained from waste palm oil would not be hampering on food product. It will reduce pollution through wastage utilization.

The objective of this study is to carry out an experimental investigation of the performance and the exhaust emission characteristics of a diesel engine fueled with Envo Diesel and coconut biodiesel blend and compared them with ordinary diesel fuel.

II. MATERIALS AND METHODS

A. Engine Test Bed

The schematic diagram of the experimental is shown in Fig.1. A new multi-cylinder diesel engine was selected for this investigation. The details specification of the used the engine can be described as:

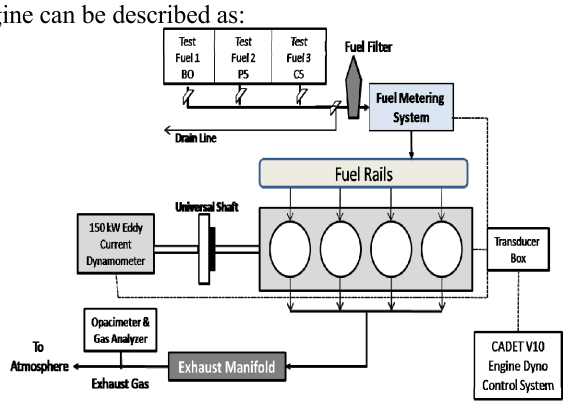

Figure 1. Schematic diagram of engine test bed.

diesel engine with multi-cylinder, water cooled, IDI, naturally aspirated, 4 cylinders, displacement 2.4L (2446 cc), compression ratio 22.3:1, throttle type nozzle, pressure circulation cooling system, continuous output 53.6 kW at 4000 rpm, Torque 155.9 Nm at 2200 rpm.

B. *Exhaust gas analyzer*

A High resolution exhaust gas analyzer was used to measure HC, CO, CO2 and NOx emissions. The analyzer was interfaced with engine controlled software so that all the data from emission analyzer and engine are logged at the same time.

C. *Test fuel*

The analysis and the preparation of test fuels were conducted at the Engine Tribology Laboratory, Department of Mechanical Engineering, University of Malaya. A total of three test fuels were selected for this investigation. The test fuels chosen are (1) 100% conventional diesel fuel (B0) supplied by Malaysian Petroleum Company (PETRONAS), (2) P5 as 5% palm diesel and 95% B0. It can be mentioned that fuel P5 is known as “Envo diesel” in Malaysia. (3) C5 as 5% coconut biodiesel and 95% B0

D. *Engine Test Procedure*

The test was conducted in Engine Tribology Laboratory, Department of Mechanical Engineering, University of Malaya. The engine test procedure and laboratory was maintained as according to SAE J1349 2007 standard. The test was conducted three times repeatedly and the repeatability results were coincided more than 96%.

E. *Fuel Properties Test*

The main properties of fuel tested such as calorific value, viscosity, specific density and flash point are tested through standard method. The ordinary diesel fuel properties are compared with blended fuels which are presented in Table 1.

TABLE I. PHYSICOCHEMICAL PROPERTIES OF TEST FUELS

Properties		**Envo diesel (P5)**	**C5**	**B0**
Density 15 ^{0}C	g cm^{-3}	0.827	0.827	0.82
Viscosity 40 ^{0}C	mm^{2}s^{-1}	4.15	3..90	3.55
Flash point	^{0}C	>140	>140	98
calorific value	MJ/kg	42.5	42.6	43

III. RESULTS AND DISCUSSION

All the test results can be discussed as follow-

A. *Engine Brake Power and Exhaust Gas Temperature*

Engine brake power versus speed at constant 85% throttle setting can be seen in Fig. 2(a). The engine was not operated on WOT due to safety in laboratory. It can be seen that brake power increases with increasing engine speed until 3000 rpm and then power starts to drop due to the effect of higher frictional force. The maximum brake power obtained by B0, C5 and P5 are 36.7 kW, 36.20 kW and 36.10 kW respectively at 3000 rpm. The lower brake power by C5 and P5 as compared to B0 is mainly due to their respective lower heating values. The average brake power all over the speed range is found as 28.28 kW, 28.08 kW and 27.94 kW by B0, C5 and P5 respectively.

The variation of exhaust gas temperatures are shown in Fig. 2(b). Exhaust gas temperatures of the blended fuels are little lower than those of the diesel fuel due to the lower heating value. However, their differences for all over the speed range are 0.77% and 0.8% lower for C5 and P5 respectively. The highest temperatures are found at 3000 rpm for all the fuels such as 735 ^{o}C, 732.5 ^{o}C and 733.6 ^{o}C by B0, C5 and P5 respectively.

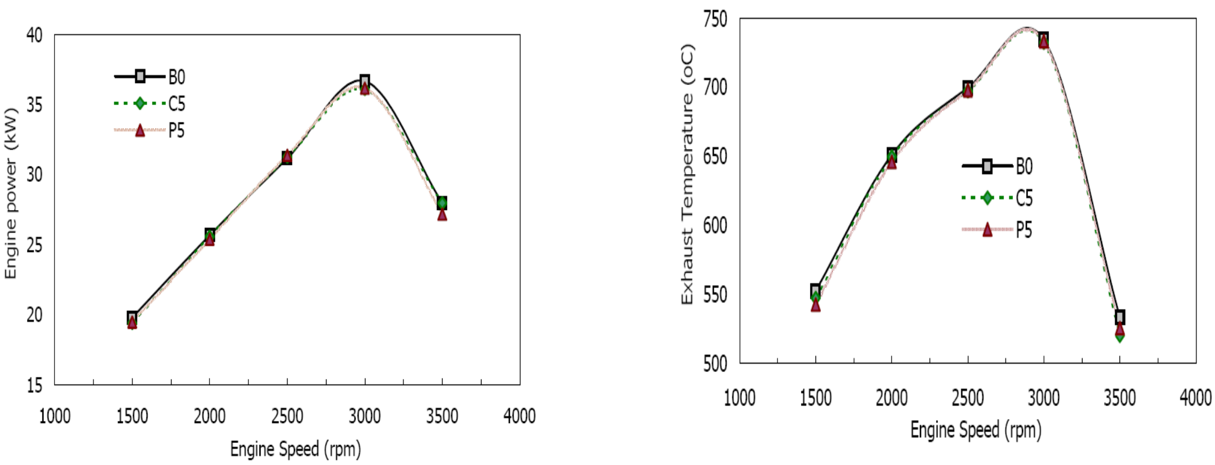

Figure 2. Engine brake power (a) and exhaust gas temperature (b) vs. engine speed at 85% throttle.

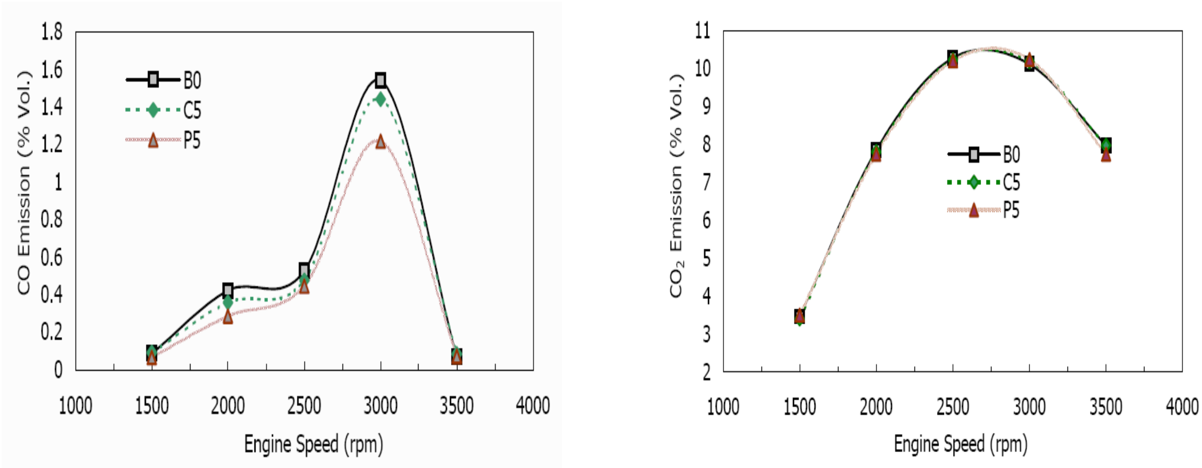

Figure 3. Carbon monoxide (a) and carbon dioxide (b) vs. engine speed at 85% throttle.

B. Carbon monoxide and Carbon dioxide

As diesel engine operates with an overall lean mixture, their CO emissions are normally lower than gasoline engines. Carbon monoxide (CO) is a toxic gas formed by the results from incomplete combustion. Emissions of CO are greatly dependent on the air-fuel ratio relative to the stoichiometric proportions. The CO emission depends on many parameters such as air–fuel ratio and fuel combustion performance into the engine cylinder. The CO emission versus engine speed is shown in Fig. 3(a). The maximum value of CO emission is found at 3000 rpm such as 1.54%, 1.44% and 1.21% for B0, C5 and P5 respectively. The lowest CO emission is found from Envo diesel (P5), followed by C5 and B0. On average, all over the speed range, C5 and P5 reduce CO emission by 7.3% and 21% respectively.

The CO_2 emissions of different fuels are shown in Fig. 3(b). Increasing CO_2 emission means better combustion phenomena. The maximum CO_2 are found between 2500 rpm to 3000 rpm due to better combustion at the current throttle-speed position. The maximum CO_2 emission is found at 3000 rpm for all the fuels as shows 10.12%, 10.19% and 10.25% by B0, C5 and P5 respectively. The Envo diesel produces more CO_2 than C5 and B0 fuels which means better combustion and it is proven that P5 produces lowest CO emission (Fig. 3(a)).

C. Unburned Hydrocarbon) and Oxides of Nitrogen

Unburned hydrocarbons (HC) are the results of fuel incomplete combustion. Similar to carbon monoxide, unburned hydrocarbons are resulted from flame quenching in crevice regions and at cylinder walls. Other causes of unburned hydrocarbons are running engine on too rich fuel air ratio with insufficient oxygen and the incomplete combustion of lube oil. Another cause is the oil film around the cylinder absorbs hydrocarbons, preventing them from burning, and then releases them into the exhaust gas. It can be seen (in Fig. 4(a)) that the lowest level of HC is produced by Envo diesel (P5) followed by C5 and B0. The maximum difference is found at 3000 rpm such as 21.8 ppm, 19.8 ppm and 14.9 ppm by B0, C5 and P5 respectively. However, all over the test cycle, it is found that C5 and P5 reduce HC emission by 5.5% and 18% respectively as compared to B0 fuel. Now, based on CO, CO_2 and HC emissions, it can be confirmed that Envo diesel P5 produce better combustion than C5 and B0 fuels.

Oxides of nitrogen (NOx) emission are shown in Fig. 4(b). The NOx emission is strongly related to lean fuel with high cylinder temperature or high peak combustion temperature. A fuel with high heat release rate at premix or rapid combustion phase and lower heat release rate at mixing—controlled combustion phase will produce NOx emission [6]. It can be seen that NOx increases with increasing engine speed due to increasing combustion temperature into engine cylinder. The maximum NOx is found at 3500 rpm such as 478.7 ppm, 462.7 ppm and 465 ppm by B0, C5 and P5, respectively. However, on average all over the speed range, C5 and P5 reduce NOx emission compared to B0 fuel by 2% and 2.50% respectively.

D. Oxygen Concentration and Smoke Opacity

The O_2 emissions of different fuels from the engine are shown in Fig. 5(a). Increasing engine speed decreases O_2 concentration due to better combustion. Between 2500 rpm to 3000 rpm, the O_2 concentration was lower as 0.7%, 0.68% and 0.71% for B0, C5 and P5 respectively. Fuels C5 and P5 show slightly higher O_2 due to contain O_2 in coconut diesel and palm diesel as compared to B0. On average, all over the speed range, C5 and P5 produce 1.30% and 2.90% higher O_2 as compared to B0 fuel.

Smoke is a suspension in air (aerosol) of small particles resulting from incomplete combustion of a fuel. Smoke produces from incomplete combustion of fuel resulting from fuel cooling effect or fuel air mixing problem etc. The relative smoke emission is shown in Fig. 5(b). It is found that the lowest smoke produces by P5 fuel followed by C5 and B0 fuels. This proves that fuel Envo diesel or P5 produces complete combustion as compared to C5 and B0 fuels. On average all over the speed range, the C5 and P5 fuels show 1.75% and 3.30% lower smoke opacity than B0 fuel.

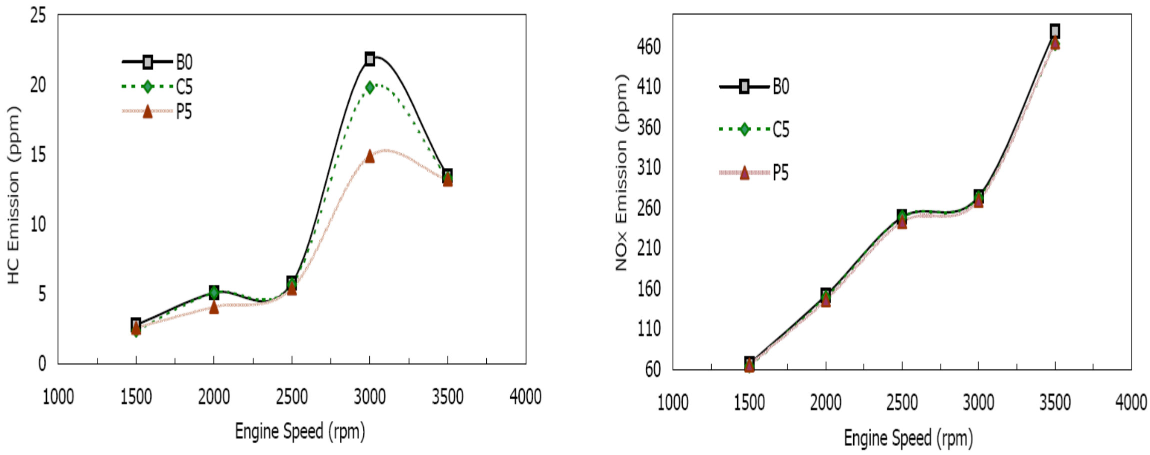

Figure 4. Unburned hydrocarbon (a) and oxides of nitrogen (b) vs. engine speed at 85% throttle.

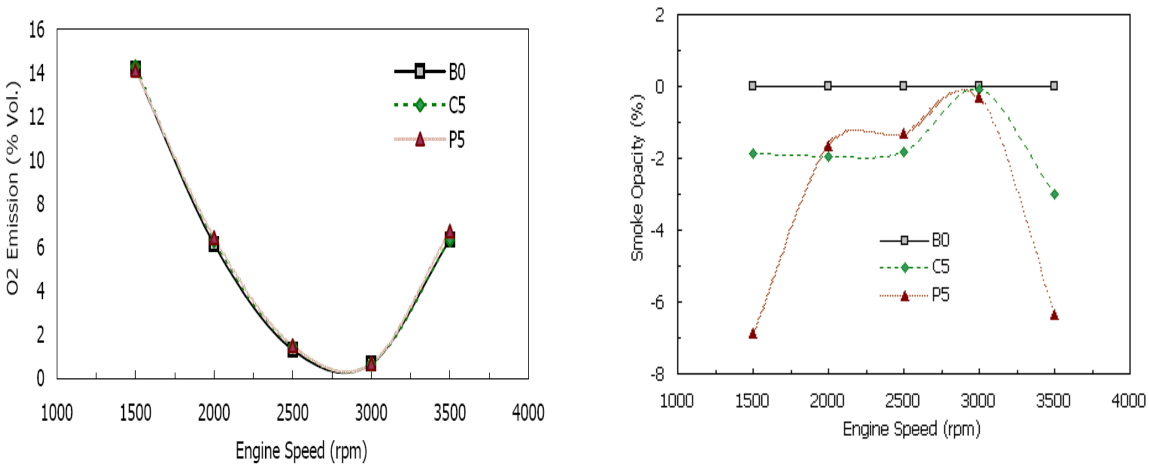

Figure 5. O_2 Concentration (a) and smoke opacity (b) vs. engine speed at 85% throttle.

IV. CONCLUSIONS

The following conclusions may be drawn from present study-

- The Envo diesel (P5) and coconut diesel (C5) produced slightly lower brake power than ordinary diesel (B0).
- The Envo diesel produced lower CO and HC as compared to C5 and B0.
- The Envo diesel increased CO_2 emission as compared to C5 and B0.
- Envo diesel and C5 reduced Nox emission by 2.50% and 2% respectively.
- The Envo diesel and C5 reduced smoke emission by 3.30% and 1.75% respectively.

Overall it is found that P5 and C5 are suitable with diesel fuel as an alternative fuel

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