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Performance and Emission of a Diesel Engine Fuelled With Preheated Palm Oil Biodiesel under High Load Conditions

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Abstract. Crude palm oil (CPO) is one of the vegetable oil that has potential for use as a fuel in diesel engine. Despite years of improvement attempts, the high viscosity and the major chemically bound oxygen component in the biodiesel fuel play as a key element during combustion process. Purpose of this study is to explore how significant the effect of preheated biodiesel blends on the engine performance and emission. The blending of biodiesel was varied from 5vol%(B5)~ 45vol%(B45) and preheated fuel temperature from 40^{o}C~60^{o}C. The engine speed was varied from 1500 rpm~3000 rpm and the load test conditions of 100% are considered. The performances parameter study of diesel engine in brake power, torque and flywheel torque are described together with the emissions parameter such as opacity, hydrocarbon (HC), nitrogen oxide (NOx), carbon oxide (CO), carbon dioxide (CO_2) and oxygen (O_2). Under high load condition, preheated biodiesel blends were found enhancing the combustion process, resulting in better performances. Increased preheated fuel temperature, higher in torque value and brake power increases significantly as the engine speed increases.

Introduction

Biodiesel is made from biological ingredients instead of petroleum. It is biodegradable and derived from many types of oil like soybean, mustard, waste cooking oil, palm oil, animal tallow and many more. Most biodiesel fuels have faced the problem where the fuels are not operating efficiently in the room temperature. In diesel engine, combustion is by nature heterogeneous combustion and the ignition process begins during early stage of combustion. It is known to control mixture formation is indispensable to improve exhaust emissions from diesel engines due to the NOx is formed at high temperature and stoichiometric mixture region; on the other hand, PM is emitted at rich region[1-5]. However, the high viscosity of biodiesel fuel (BDF) that affected the fuel-air premixing and ignition process during combustion process [6-9]. For that reason, preheating of BDF is one of the methods to lower the viscosity of the biodiesel fuel because the viscosity of the fuels is proportionally decreased as the temperature increases.

S. Bari et al. investigated the effect of preheating of crude palm oil (CPO) on injection system, performance and emission of a diesel engine. Author reported that the fuel temperature have a significant effects on brake specific fuel consumption (bsfc) when running CPO at different loads and proposed the fuel must be heated to at least 60 ^{o}C for smooth flow because it will start to solidify and hinder smooth flow below 60 ^{o}C. E. Alptekin et al. [10] reported that fuel properties of biodiesel such as cetane number, heat of combustion, specific gravity, and kinematic viscosity influence the engine combustion performance and emission characteristics because it has different physical and chemical properties than petroleum-based diesel fuel. Under high fuel temperature, fuel spray of vegetable oils undergoes chemical reactions, which include thermal cracking and polymerization at the spray core (producing heavy, low-volatility compounds)[11]. The air-fuel mixing process is affected by the difficulty in atomization of the heavy compounds. The resulting locally rich mixtures cause more CO to be produced during combustion due to the lack of oxygen. The formation of NO is favored by higher combustion temperature and availability of oxygen. Unlike diesel, vegetable oils such as CPO also contain oxygen that together with higher combustion temperatures, favors production of more NO than diesel fuel combustion[12].

In this study, biodiesel from CPO has been blended and preheated before going through properties and performances test to analyze the quality of CPO biodiesel blend as an ignition fuel. The preheated biodiesel (40°C, 50°C and 60°C) was tested in diesel engine at three different biodiesel ratios which are B5, B10 and B15. To make further analysis for this study, diesel fuel also has been tested to make the comparison between diesel fuels and preheated biodiesel result. The performance parameters consist of brake power (BP), torque and flywheel torque. For the engine emission, the properties that being tested consist of hydrocarbon (HC), oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxide (NOx) and smoke opacity.

Table 1: Properties of preheat diesel oil blends

Fuel	Flash Point (°C)				Acid Value (mg NaOH/g)				Density (g/cm3)					Water Content (ppm)				Viscosity (Cp)			
	Preheat temperature				Preheat temperature				Preheat temperature					Preheat temperature				Preheat temperature			
	27.5	40	50	60	27.5	40	50	60	15	27.5	40	50	60	27.5	40	50	60	27.5	40	50	60
D	71.5	73	75.5	78.5	0.673	0.617	0.561	0.505	0.847	0.829	0.821	0.819	0.811	57	55.4	48.3	46.7	3	2.9	2.5	2.4
B5	85	88.5	89	91.5	0.673	0.617	0.561	0.449	0.851	0.845	0.83	0.825	0.815	140	102.8	76.6	69.9	4	3.6	3.4	3.25
B10	85.5	93.5	96.5	99	0.729	0.673	0.561	0.505	0.854	0.852	0.836	0.832	0.821	146.1	108.7	95.1	76.4	4.1	3.8	3.5	3.37
B15	87	94.5	99.5	102.5	0.954	0.898	0.673	0.561	0.863	0.854	0.844	0.837	0.836	191.9	112.4	101.7	73.1	4.3	3.9	3.7	3.45

Experimental Setup

The standard diesel (OD) was purchased at the commercial pump station and the blending process was done in our automotive laboratory by standard methods. The study used three kinds of BDF derived from CPO which provided by our biodiesel pilot-plant. The important properties of the blends and preheat diesel oil blends are shown in Table 1. In this research, the kinematic viscosity and density properties of palm oil blend were measured by Viscolite 700 model VL700-T15 and Metter Toledo Diamond Scale modeled JB703-C/A, respectively. The water content was measured using Volumetric KF Titrator model v20 and the flash point measured by Pensky-Martens PMA 4. The schematic arrangement of experimental set up including the preheat tank are shown in Figure 1. The preheat fuel tank of the oil blends was accomplished by a new develop tank attached to the engine. Preheat tank was used to preheat the biodiesel blends ratio according to the temperature of 40°C, 50°C and 60°C. The details of engine test specification are given in Table 2.

Table 2: Engine test specification

Engine	Mitsubishi
Model Code	S-L049GV-NTD
Engine Model	4D56 (turbocharger)
Engine type	Serial 4 cylinder OHC turbo
Fuel type	Diesel
Fuel system	Distribution type jet pump
Bore/stroke (mm)	91.1/ 95
Maximum power	85 ps (62.52 kw) / 4200 rpm
Maximum Torque	20.0kg-m(196 N-m)/2000rpm
Displacement	2476 cc
Compression Ratio	21.0
Supercharger	TURBO
Vehicle Weight	1590 kg

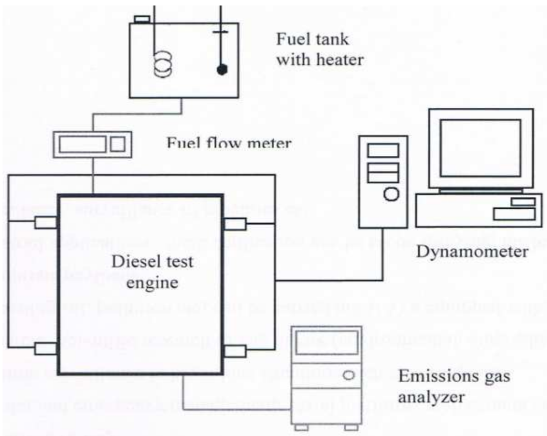

Figure 1: Experimental set up

A series of measurements were conducted on a test commercial vehicle (Mitsubishi Pajero) intended for automotive application. The experimental program was carried out using the commercial vehicle of four-cylinder four stroke-cycle DI diesel engine (Mitsubishi S-L049GV-NTD). The engine is equipped with turbocharged with maximum power of 62.52 kW (4200 rpm) and compression ratio of 21:1.The engine fuel consumption was measured using a precision ONOSOKKI volumetric fuel flow meter, and are pegged between the preheat fuel tank and the fuel pump. The engine was loaded by Dynapack Chassis Dynamometer Machine model 4022. The engine speed was adjusted at variant of 1500, 2000, 2500 and 3000 rpm. The chassis dynamometer unit loads was held fixed at high 100% thus covering the typical and high load operation of the combustion regime. The vehicle performance data comprised power (kW), flywheel torque (Nm) together with the exhaust emissions measurements. Autocheck 5-Channel Gas Emission Analyzer is used to determine the emissions of the engine such as carbon monoxide, carbon dioxide and oxygen from exhaust. Smoke emission was measured by Autocheck Smoke Opacity Meter and opacity range 0~100%. Dragger MSI EM200-E was used to measure the differential pressure, temperature and a wide range of gas concentration with high precision.

Result and Discussion

The effects of preheat blending ratio of B5 on performance and emissions was investigated at the base standard diesel (OD) and B5 without preheat (NB5) for preheat biodiesel of 40°C (T40B5), 50°C (T50B5) and 60°C (T60B5) for engine speed of 1500, 2000, 2500 and 3000 rpm. The engine was operated under 100% load operations. Figure 2 depicts the variation in combustion emission characteristics as preheat fuel temperature is varied. As seen in Fig. 2, increased preheat fuel temperature thus predominantly influences the reduction of CO and CO_2, while having big impact on the increasing of NOx and more higher under preheat fuel of 60°C especially at 2000 rpm. It seems that the low viscosity of fuel due to the higher fuel preheat enhanced the fuel-air premixing thus influences the higher NOx. Nevertheless, the increasing of preheat fuel temperature has not influences to the reductions of HC in overall combustion process.

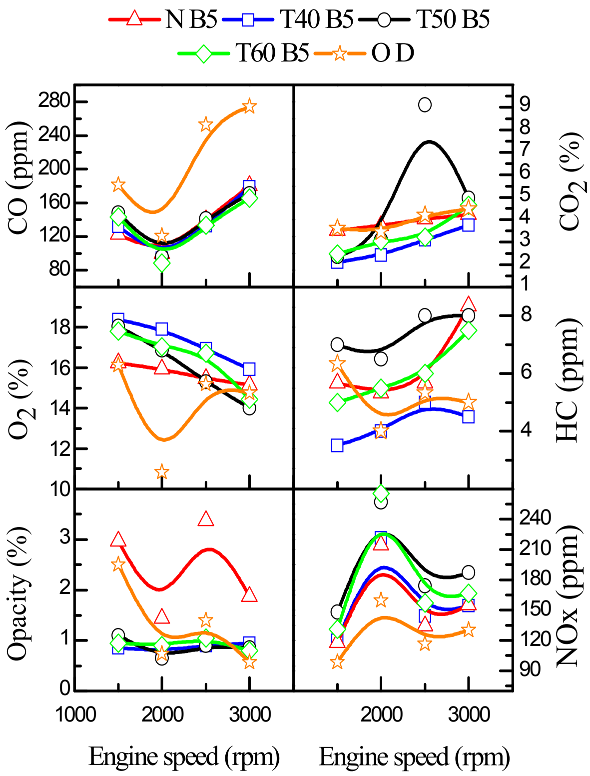

Figure 2: Effects preheated B5 biodiesel blends and engine speed on emissions

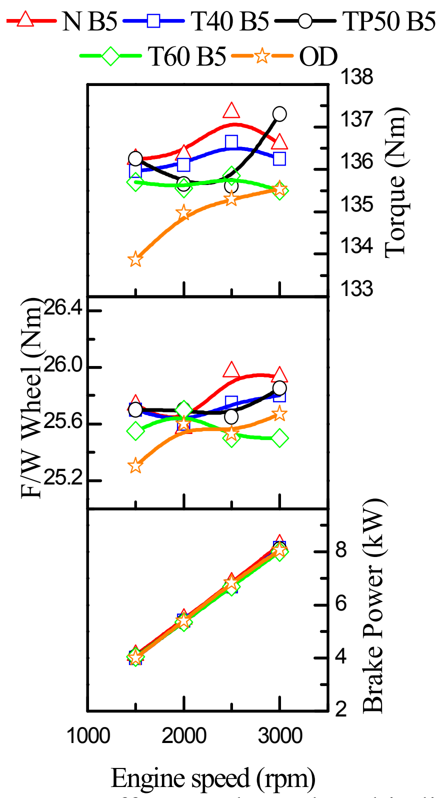

Figure 3: Effects preheated B5 biodiesel blends and engine speed on performance

The behavior of emissions characteristics and combustion process influences from preheat fuel temperature can be examined more conveniently by considering the variation in engine performance as shown in Fig.3. Under high load condition and fuel blend of B5, little effect of preheat fuel can be seen in the instantaneous of F/W wheel compared to the variant in engine torque. Accordingly, the increasing of fuel temperature are not influences the changes of the engine power due to the cumulative brake power development are nearly parallel at all engine speed.

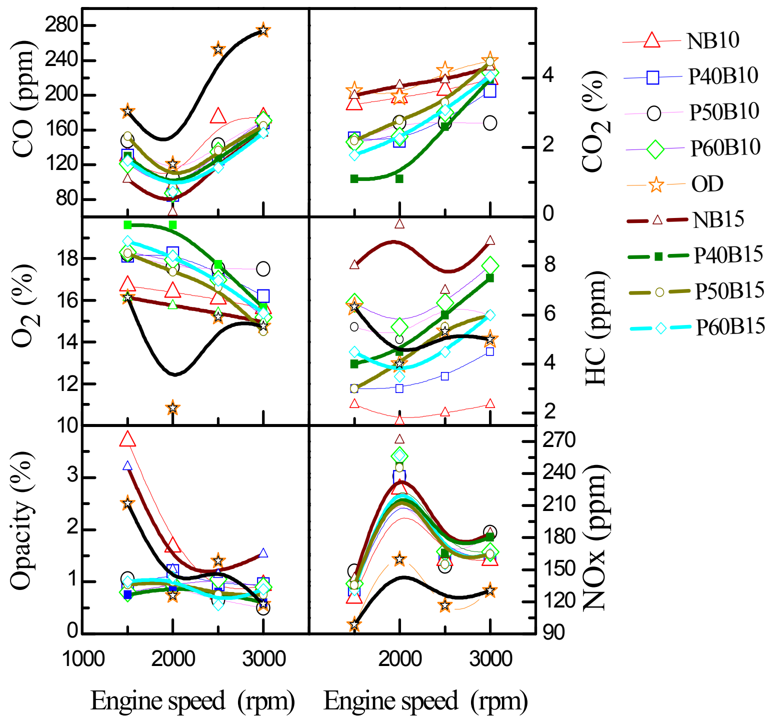

Figure 4: Effects preheated biodiesel blends and engine speed on emisions

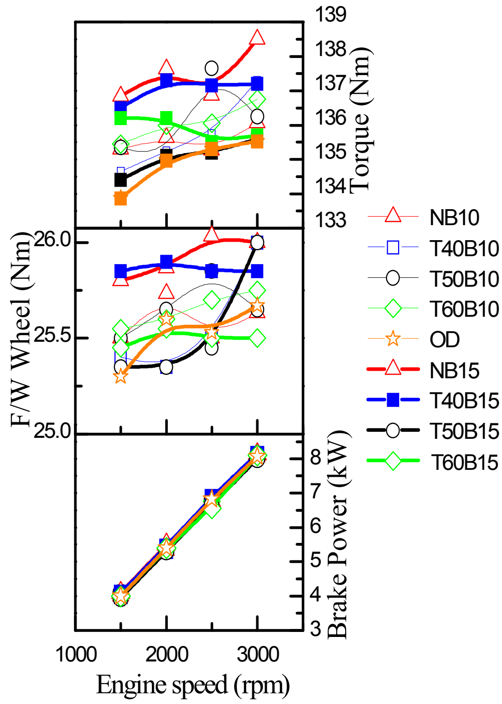

Figure 5: Effects preheated biodiesel blends and engine speed on performance

Next, this section investigated the effects of variant blending ratio and preheated fuel on exhaust emission and engine performance. To investigate the effects of variant blending ratio temperature under high load condition on exhaust emissions and performance, without preheat fuel blends of B10(NB10) and B15(NB15) were employed at the base condition. Figure 4 depicts the variation in the emissions such as smoke opacity, HC, O_2, CO, CO_2 and NOx with different engine speed, fuel temperature and variant BDF percentage. As seen in Fig.4, increased preheat fuel influences to the NOx emission achieved the peak value at 2000 rpm but decreases when the engine running above the speed of 2000 rpm compared to the diesel fuel. The increasing in NOx emission with preheating may be attributed to the increase in the combustion gas temperature with increase in fuel inlet temperature. On the other hand, preheated at 40ºC and 60ºC give better emission production while for B15 biodiesel blend, preheated at all testing temperature will give the better result of HC emission compared to its normal temperature condition. The increasing of biodiesel concentration in blends has a beneficial in HC emissions reduction. It can be conclude that preheated biodiesel promoted better HC emission because of the complete combustion of biodiesel within the combustion period. In addition, preheated biodiesel produced the reduction of opacity emission. This might due to the reduction in viscosity and subsequent improvement in spray, fuel-air mixing and combustion characteristics by preheating.

The variations of engine performance with engine speed and preheat of diesel blends under high load are shown in Fig. 5. It was observed that the increasing preheat fuel under high blending ratio produced more torque. The brake power increases much faster with the increasing of engine speed but the similar in the value increment. This may be attributed to complete combustion because of oxygenated fuel. The complete combustion and fully utilized high oxygen content in fuel associated with the slight changes of the brake power. The value of torque produced for all type of biodiesel blend ratio higher compared than standard diesel, the value produced getting lower as the temperature increases. Preheated B10 biodiesel blend at 50ºC shows the obvious torque result at 2500 rpm.

Conclusion

Engine performance and emissions results of preheat biodiesel (BDF) derived from different CPO (B5, B10, B15) under high load conditions were compared with the results obtained with standard diesel and without preheat. The results of the study may be summarized as follows:

1. Performance in term of torque and flywheel torque are slightly increased than standard diesel for higher preheat fuel.
2. The production of NOx did not show any improvement when using preheated CPO biodiesel fuel. The increment between the different inlet temperature just give slightly change for the NOx emission. However, preheated CPO biodiesel fuel reduces CO and CO_2 emissions as compared to the diesel fuel. The effect of temperature only give the slightly changes to CO emission for all the fuel tested.

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