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Performance and Emissions of Preheated Biodiesel on a Compression Ignition (CI) Engines

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Abstract
Diesel engines are still widely needed and applicable to agriculture, construction, light duty passenger car and heavy duty vehicles. In recent years, limited supply of fossil fuel makes alternative sources of fuel especially biodiesel receiving a lot of attention in the automotive industry. However, in using biodiesel as fuel had created poor fuel-air mixing that generally will produce lower performance and higher emissions than diesel fuel. This phenomenon associated with the fuel properties especially viscosity that higher compared to diesel fuel. The aim of this study is to investigate the effects of preheated biodiesel derived from crude palm oil with 5% blending ratio (B5) at 40°C, 50°C and 60°C on performance and emissions of diesel engine under two different load conditions, which are 50% load and 100% load. A four-cylinder four strokes cycle, water cooled, direct injection engine was used for the experiments and the engine speed was varied from 1500 rpm up to 3000 rpm with the 500 rpm increment. Dynapack chassis dynamometer was used to perform the performance data while Autocheck gas/smoke analyzer and Drager were used to obtain the emissions data. Increased of load and biodiesel fuel temperature promotes more rapid engine performance but exhibit relatively small variations in emissions production.

Introduction
Biodiesel is an alternative fuel that receiving a lot of attention nowadays due to its availability sources and renewability. Source of biodiesel may be divided into two categories; vegetable oils and animal fats. However, vegetable oils have become the main actor in producing biodiesel such as soybean oil, raw rapeseed oil, waste cooking oil, cottonseed oil, sunflower oil, crude palm oil and many more. The usage of this vegetable oil is due to the great fuel properties such as flash point and acid value that comparable to the diesel fuel[1-2]. In Malaysia, abundantly sources of crude palm oil have resulted on the large numbers of research and development was conducted. It can be use in diesel engine directly without major modification. However, lack of study is carry out on the preheat biodiesel blends before entering to the combustion chamber.

Most biodiesel fuels have faced a problem where the fuels are not operating effectively in cold weather. It is due to the fuel properties such as viscosity that affected the fuels flow rate and poor fuel atomization during combustion process [1]. Viscosity will gradually decrease as the temperature increase and it will influence the fuel-air mixing due to the changes of spray evaporation and consequently influence the combustion, performance and emissions of diesel engine. Lots of researchers have reported that use of vegetable oils or its blends (higher viscosity) without preheat effects on fuel droplet formation, poor atomization, vaporization and air fuel mixing process [3-7].These effects cause important engine failures such as fuel filter clogging, piston ring sticking, injector choking, carbon formation deposits and rapid deterioration of lubricating oil [4-5]. Other than that, it also leads to high smoke, HC and CO emissions [8-9]. Moreover, increasing fuel temperature or heating also will ease the problem of injection process because it results in a decrease of the arithmetic diameter of the fuel droplets due to the effect of surface tension and viscosity changes with temperature [10-11]. Thus, it gives better spray formation and combustion process.

Experiment Setup

Fuel-The study used biodiesel fuel derived from crude palm oil (CPO) with 5% blending ratio. The fuel was tested at three different fuel temperatures; 40°C, 50°C and 60°C and also at three different load conditions; 0% load, 50% load and 100% load. The properties of the tested fuel were shown in Table 1. The grade II diesel fuel was assigned as a standard reference for the testing. Then, the results from all preheat temperatures and load conditions were compared to the grade II diesel fuel. The flash point, density, water content and viscosity of tested fuel were measured by Pensky-Martens PMA 4, Metter Toledo Diamond Scale modeled JB703-C/AF, Volumetric KF Titrator model v20 and Viscolite 700 model VL700-T15 respectively.

Table 1: Fuel properties

Properties	Temperature (°C)	B5
Flash Point (°C)	27.5	85.0
	40	88.5
	50	89.0
	60	91.5
Density (g/cm^3)	15	0.851
	27.5	0.845
	40	0.830
	50	0.825
	60	0.815
Water Content (ppm)	27.5	140.0
	40	102.8
	50	76.6
	60	69.9
Viscosity (cP)	27.5	4.0
	40	3.6
	50	3.4
	60	3.25

Table 2: Engine specification

Type	Mitsubishi
Model code	S-L049GV-NTD
Engine model	4D56 (Turbocharger)
Engine type	Serial 4 cylinder OHC turbo
Fuel system	Distribution type jet pump
Bore/Stroke (mm)	91.1/95
Maximum power	85 ps (62.25 kW) / 4200 rpm
Maximum torque	20.0 kg-m (196 N-m) / 2000 rpm
Displacement	2476 cc
Compression ratio	21.0
Cooling system	Water cooled

Apparatus-In order to obtain the data of performance and emissions of preheated biodiesel fuel, a series of experiments were conducted using compression ignition (CI) engine. The engine specification was detailed in Table 2. The engine was coupled to a chassis dynamometer that produced performance parameters such as torque and brake power. The dynamometer used was Dynapack Chassis Dynamometer model 4022 that capable to simulate the actual situation during road operation and also capable to measure horse power until 850HP. The data obtained at four different engine speed; 1500rpm, 2000rpm, 2500rpm and 3000rpm.The load were varied at 0%, 50% and 100% load conditions. Two types of emissions analyzer were used to produce emissions data. There were Autocheck gas/smoke opacity meter analyzer and Drager MSI EM200-E. The Autocheck was used for hydrocarbon (HC), carbon dioxide (CO_2), oxygen (O_2) and opacity while Drager was used for oxides of nitrogen (NO_x) and carbon monoxide (CO). The probes of both emissions analyzer were located at the center of the exhaust pipe as per standard operation procedure of the equipments. The biodiesel fuel was heated up to the required temperature using modified fuel heater tank. The fuel heater tank was installed as short as possible to the engine in order to reduce the heat loss along the fuel line during experiment. The fuel line was insulated using a layer of asbestos and aluminium foil also to reduce the heat loss during experiment. Figure 1 shows the schematic diagram of fuel heater tank and Figure 2 shows the insulated fuel line.

Schematic diagram of the experimental setup is shown in Figure 3. To minimize errors and obtain better results, the experiment conducted were repeated three times for each data at the same operating condition.

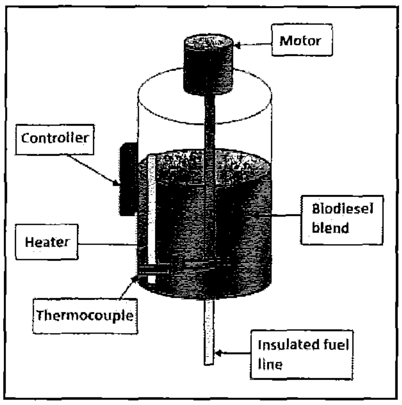

Figure 1: Schematic diagram of fuel heater tank

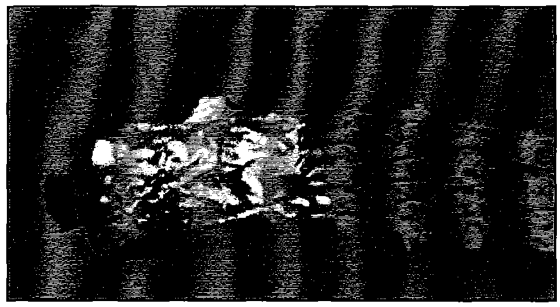

Figure 2: Insulated fuel line

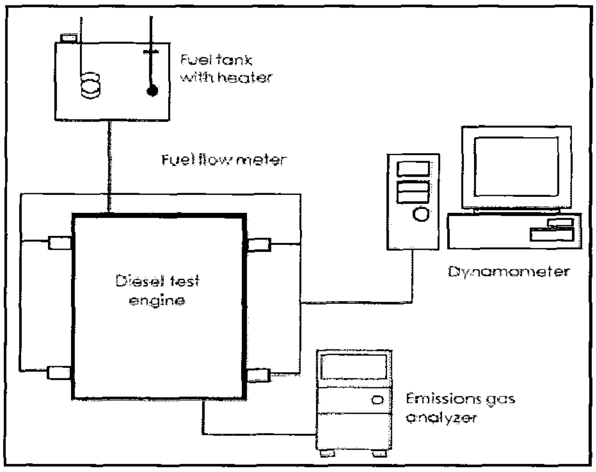

Figure 3: Schematic diagram of experimental setup

Result and Discussion

Figure 4 depicts the performances of preheated B5 at two different load conditions. B5 were tested at three different preheat temperatures and the graph of torque, flywheel torque and brake power were plotted accordingly against engine speed. The value of torque and flywheel torque produced were increase as the load increase. However, the brake power only increases after 100% load condition. The preheat temperature seems not strongly influence the brake power produced at both load conditions. Generally, the preheat B5 created higher value of torque and flywheel torque compared to diesel fuel at almost engine speed for all load conditions. This may be attributed to the effects of preheat that result on the better combustion characteristics because of decreased in viscosity and improved volatility. Nevertheless, the preheat temperature is expected to be not strongly influenced the pattern of performance produced. It is clearly shown at the torque and flywheel torque graph of 50% and 100% load in Figure 4.

Figure 5 shows the effects of preheated B5 at 50% and 100% load conditions respectively. The graph illustrates the emissions of CO, O_2, opacity, CO_2, HC and NO_x against engine speed. The CO emission of preheat B5 blends was lower compared to diesel fuel at both load conditions and its dominantly lower at 2000 rpm of engine speed. At both load conditions, the increasing of temperature seems not affected to the decrement of CO produced. On the other hand, O_2 was decreased as the engine speed increased and the value was higher compared to diesel fuel and unheated B5. Meanwhile, CO_2 of all preheat B5 blends show the increment pattern as the engine speed increase and produced lower CO_2 compared to diesel fuel and unheated B5 for both loads carried out. This may be attributed to the carbon content and oxygen element that moderately lower in the same volume of fuel consumed.

For HC emission, the average HC produced was lower at 40°C preheat temperature compared to diesel fuel and unheated B5 for both load conditions. This could be due to the higher oxygen content of B5 that may improve the combustion process and preheat B5 decreases the viscosity which improves the oxidation of B5 in the cylinder. However, at 50°C and 60°C of preheat temperature of B5 blend, HC produced was averagely higher than diesel fuel and unheated B5 also for both load conditions. The highest NO_x emission takes place at 2000 rpm engine speed unexpectedly for both load conditions and the preheat B5 produced higher NO_x compared to diesel fuel and unheated B5. In addition, increase the fuel temperature promotes the NO_x emission due to the changes of fuel properties that influence the early stage of combustion. This behavior may associate with the fuel temperature that contributes to the increase of combustion gas temperature and better fuel-air mixing especially at ignition delay period. The opacity produced was averagely lower than diesel fuel and unheated B5 for both load conditions. This may be due to the reduction in viscosity that subsequently results on the improvement in spray characteristics, better air-fuel mixing and better combustion characteristics.

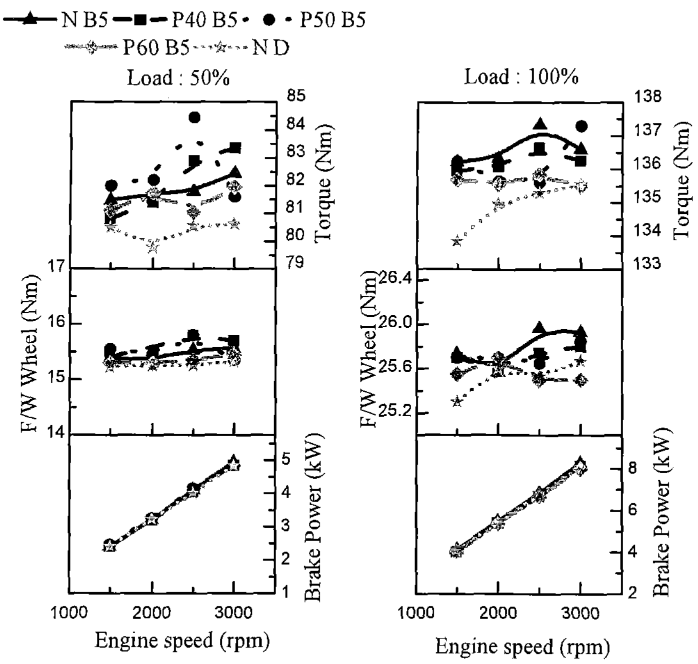

Figure 4: Performances of preheated B5 at two different load conditions

Conclusion

As conclusion, performance parameters seems not strongly influenced by the increasing of load condition and fuel temperature as compared to the diesel fuel. For the emissions, HC produced was found better at 100% load condition with 40°C of preheat temperature. This behaviour could be associated with the higher oxygen content that improves the combustion process and preheat decreases the viscosity which improves the oxidation in the cylinder. The CO emission produced was found better with the preheat fuel temperature but NO_x formation increased as the fuel temperature increase is expected to be strongly influenced by increasing of ambient temperature in chamber during combustion process.

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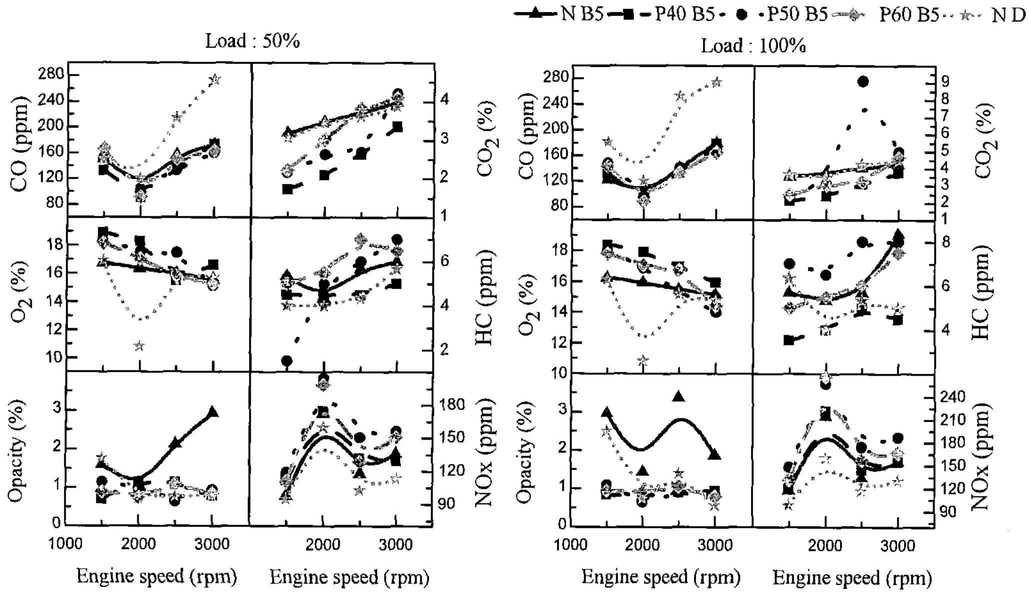

Figure 5: Emissions of preheated B5 at two different load conditions

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