Effect of Ceiba pentandra Biodiesel/Dexlite Diesel Blends on the Four-Stroke Diesel Engine Performances

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Effect of *Ceiba pentandra* Biodiesel/Dexlite Diesel Blends on the Four-Stroke Diesel Engine Performances

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Abstract. The increasing number of motorized vehicles causes an increase in fuel consumption. Meanwhile, fuel consumption in Indonesia is inversely proportional to the amount of oil production in Indonesia. One of the solution in by using biodiesel from kapok (*Ceiba pentendra*) seed as a diesel fuel blends. In this research, blends of dexlite (diesel fuel)/*Ceiba pentandra* biodiesel was studied on the four stroke diesel engine performance. Four different fuel blends (B10, B20, B30 and B40) and B0 (pure dexlite fuel) were prepared for the engine performance test. The engine performance shows that addition of biodiesel to diesel fuel gave lower torque than the dexlite fuel. Biodiesel blends also have lower brake power compared to the dexlite fuel. Among different biodiesel blends, A 10% biodiesel blend shows the best engine performance in terms of engine torque and brake power.

1. Introduction

Recently, major utilization of fossil fuel in the world became a concern to find an alternative fuel due to its environmental impact and the diminishing of its reserves. Biodiesel is considered as an alternative energy source in view of it is renewable, harmless, safe and biodegradable. More than 95% of biodiesel in the world is produced from edible oils since they have high biodiesel yield and easily processed due to their low free fatty acid [1]. In recent times, the demand for edible vegetable oil has increased and there are concerns such as high cost and negative impact on food chain [2]. There are several sources of non-edible oils that can be used for biodiesel production such as *Jatropha carcus*, *Pongamia pinnata*, *Callophyllum inophyllum*, rubber seed, *Azadirachta indica*, *Madhucha indica*, *Simmondsia chinensis*, *Ceiba pentandra* and microalgae [2]. Kapok (*Ceiba pentandra*) seed oil is among the prospective non edible oil for biodiesel synthesis.

Ceiba pentandra or locally known as kapok can be easily found in tropical countries such as Indonesia, Malaysia, Philipines, several parts of America and Africa [3]. Generally, *C. Pentandra* fibers are used as a stuffing material for beds, pillows, upholstery and substitute for absorbent cotton in surgery [1]. *C. Pentandra* seed has higher oil yields (26.4 wt.%) compared to edible oil such as soybean (18-22 %). Due to this properties, it makes *C. Pentandra* become a promising non-edible oil source for biodiesel production [4,5].

Transesterification is a conventional method to produce biodiesel from vegetable oils. This reaction usually reaches equilibrium state slowly, leading to a low conversion and high energy consumption

[6]. Kusumaningtyas et al. had utilized an enhanced batch reactor for producing biodiesel from kapok seed oil. It was found that it has an optimum biodiesel yield at 99.82%, which was obtained at the operating condition of: oil to methanol molar ratio of 1:6, reaction temperature of 60℃, catalyst concentration of 0.5%, and ultrasonic frequency of 28 kHz for 60 minutes reaction time. The biodiesel yield was found to be higher compared to the yield obtained from conventional process 91 - 97% [1,7,8]. It is reported that the feedstock blends could improve the fuel properties [9]. In this paper, *C. Pentandra* is blended with dexlite a diesel fuel produced by Indonesia oil and gas company PT. Pertamina. Dexlite has a minimum cetane number of 51 and a maximum sulphur content of 1,200 parts per million (ppm). It also contains 20% Fatty Acid Methyl Ester (FAME) [10].

From the previous studies, it was found that an addition of B20 into diesel fuel can increases the engine performance. However, a higher biodiesel blends compositions decrease the engine performance. While an SO_2 emissions, CO and NO_x particles, decrease constantly with the increasing of biodiesel content in the fuel blends [11,12]. Another study also stated that the emissions of CO, CO_2, and HC from diesel fuel are higher than the emissions produced by biodiesel blends [13]. Recently, the diesel engine performance such as engine torque, brake power, brake specific fuel consumption, brake thermal efficiency, exhaust gas temperature and the emissions was tested by using biodiesel obtained by using a conventional method [1,14–16].

In this study, various ratios of *Ceiba pentandra* biodiesel/diesel blends were used to investigate the four stroke engine performances (engine torque and brake power). The biodiesel *Ceiba pentandra* biodiesel was produced through ultrasound-enhanced transesterification reaction [17].

2. Materials and Methods

2.1. Materials

In this research, dexlite fuel was obtained from the Indonesian oil and gas corporation (PT. Pertamina). *C. Pentandra* biodiesel oil was produced in Chemical Engineering laboratory of Universitas Negeri Semarang by following the methods from previous studies [17]. Optimum operating condition was used in the biodiesel production.

2.2. Methods

First, bodiesel and diesel fuel was analyzed its physicochemical properties at the Laboratory of Natural Oil, Gas and Coal Technology, Universitas Gadjah Mada. The fuel used in this study is varied at four different volume basic ratios which are 10% (B10), 20% (B20), 30% (B30) and 40% B(40). A pure dexlite fuel was also prepared as a controlled variable with 0% additional of biodiesel (B0). The engine tests were performed at Mechanical Engineering of Universitas Negeri Semarang by using Dynamometer pull type LPS 3000 and four stroke diesel engine. A schematic of the experimental setup for diesel engine performance test can be seen in Figure 1. The performance test was aimed to measure the engine torque and engine brake power.

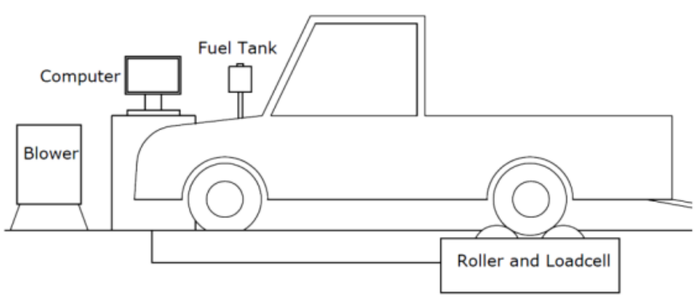

Figure 1. Schematic experimental setup for engine performance test.

The diesel engine used for this research is a diesel engine on an Isuzu Panther vehicle 2015. The specifications of the vehicle used are: MSG5K engine; 2,499 cc cylinder capacity; with maximum power of 80 PS / 3,500 rpm; maximum torque of 19.5 kgm / 1,800 rpm; number of cylinders: 4 in line; diameter x stroke 95.4 mm x 87.4 mm; and has 5 speed transmission.

Data obtained from the roller and load cell of dynamometers as shown in Figure 1 were processed and analyzed by using a computer system, so torque and diesel engine power of the tested vehicle can be produced.

3. Results and Discussion

3.1. Characteristics of Ceiba pentandra Biodiese/Diesel Fuel

The properties of dexlite and *Ceiba pentandra* biodiesel were measured at Chemical Engineering Laboratory of Universitas Negeri Semarang and Laboratory of Natural Oil, Gas and Coal Technology, Universitas Gadjah Mada. The detailed characteristics of biodiesel and dexlite are shown in Table 1.

Table 1. Properties of Dexlite diesel fuel and *Ceiba pentandra* Biodiesel.

Properties	Unit	*Ceiba pentandra* Biodiesel	*Dexlite*
Calorific Value	MJ/kg	39.74	44.45
Flash Point	°C	170	71
Density (40 °C)	g/ml	0.862	0.828
Kinematic viscosity (40 °C)	cSt	5.771	3.52

Generally, *C. pentandra* Biodiesel characteristics were already fulfill the requirements of Indonesia national Standard Certified Products for biodiesel (SNI). The SNI Standard for biodiesel’s calorific value, flash point, density and kinematic viscosity were 37 MJ/kg, 100 ^{O}C, 0.85 – 0.89 ml and 2.3 – 6.0 cSt. However, differences in the physic- chemical properties of biodiesel and diesel fuel make a difference in the basic properties of biodiesel blend which further affect the engine performance and emission [18].

The performance test in this study will measure the power and torque of diesel engine by using a different combination of diesel fuel with *C. Pentandra* Biodiesel. The combinations were B0 (100% Dexlite), B10 (blends of 90% Dexlite and 10% Biodiesel), B20 (blends of 80% Dexlite and 20% Biodiesel), B30 (blends of 70% Dexlite and 30% Biodiesel) and B40 (blends of 60% Dexlite and 40% Biodiesel).

3.2. Effect of Biodiesel Blends on the Diesel Engine Torque

Figure 2. Shows the variations of engine torque with engine speed for various diesel fuel blends. It can be seen that pure dexlite (B0) have a greater torque compared to dexlite blends with *C. pentandra* biodiesel.

In general, maximum torque on diesel engine occurs from 2,000 rpm to 2,500 rpm, meanwhile in this research we found that the maximum engine torque was found at engine speed of 3,000 rpm. It can be concluded that the engine torque at 2,000 rpm well be lower that engine torque at 2,500 rpm. From Figure 2, it can be seen that the engine torque is shifted after an addition C. Pentandra biodiesel oil in the dexlite fuel. For the B10 diesel fuel, the torque is constantly decreasing from 121.5 Nm to 92 Nm. While, other diesel fuel torque variations is increasing at the speed of 3000 rpm and then it decreases continuously until the speed of 5000 rpm. B0 has the lowest torque at 2500 rpm with only 103.5 Nm. However, it has the largest torque with 119.15 Nm at 3000 rpm and constantly gave the highest torque for the rest engine speed. Low engine torque at the highest speed was caused by the increasing of frictional force. Engine torque also can be affected by the energy from fuel combustion, meanwhile the fuel combustion energy is depended on the fuel calorific value [19]. Since the diesel fuel is mixed with the C. Pentandra biodiesel oil which has lower calorific value, it might cause the blends calorific value is also decreasing.

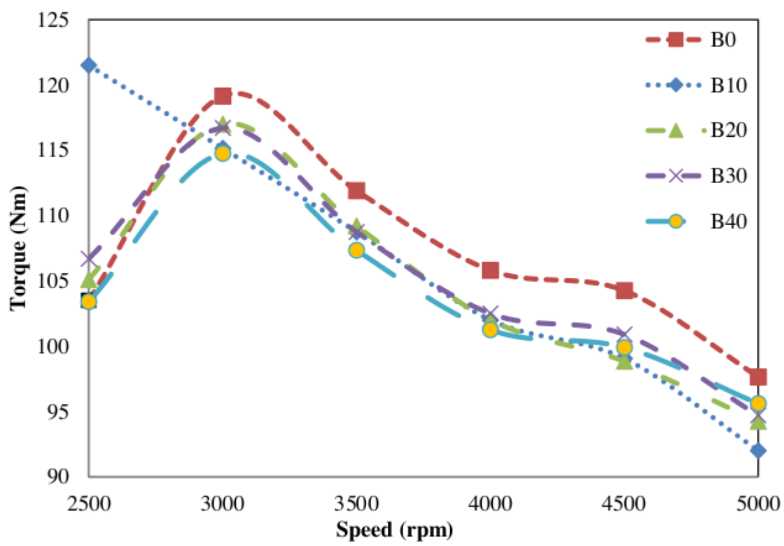

Figure 2. Effects of engine speed to the engine torque for different diesel blends.

Calorific value is also affected by the fuel's density, which is inversely proportional to the density. At the same fuel volume, the calorific value is decreasing as the increasing density of the fuel. It is in line with the data shown in Table 1, where biodiesel has a higher density compared to dexlite. However, in this research specific fuel consumption test was not carried out since the throttle is used as the test variable.

Dexlite fuel (B0) has the highest average torque engine with 107.04 Nm followed by B10, B30, B20 and B40 with average torque engine of 106.40 Nm, 105.04 Nm, 104.4 Nm and 103.78 Nm respectively. It can be concluded that B10 torque engine performance is closed to the pure diesel engine performance with only 0.6% difference.

3.3. Effect of Dexlite Blends on the Diesel Break Horse Power

Figure 3 shows the effect variations of break horse power with engine speed for various biodiesel fuel blends.

From Figure 3, it can be seen that the addition of *C. Pentandra* biodiesel in the diesel fuel is not significant to the brake horse power. At 500 rpm, brake horse power of B0 is 51.11 kW, the brake power decreased to 48.15 with an addition of 10% C. Pentandra biodiesel. At the same speed, B20 and B30 output power is slightly higher than B10 which is 49.15 kW and 49.585 kW respectively. While, B40 has the largest output power among the blended diesel fuel with biodiesel, it gave an output power of 50.075 kW.

The brake horse power value of an engine is influenced by a frictional loss or also known as a mechanical friction loss. With the increasing of speed engine, it will increase the friction between piston ring and the cylinder. Operating a high speed engine with longer duration will decrease the mechanical power. Brake horse power also influenced by the viscosity of fuel. C. Pentandra biodiesel has a higher viscosity than dexlite fuel. Higher viscosity of the fuel can cover the cylinder, therefore the piston will have a smoother movement [20].

Based on the average value of the power output of the engine, B0 has the highest power among all the biodiesel blends with 41.678 kW. Meanwhile, the blend of dexlite with 10% of C. Pentandra biodiesel (B10) produces 40.889 kW and the result is in line with [19].

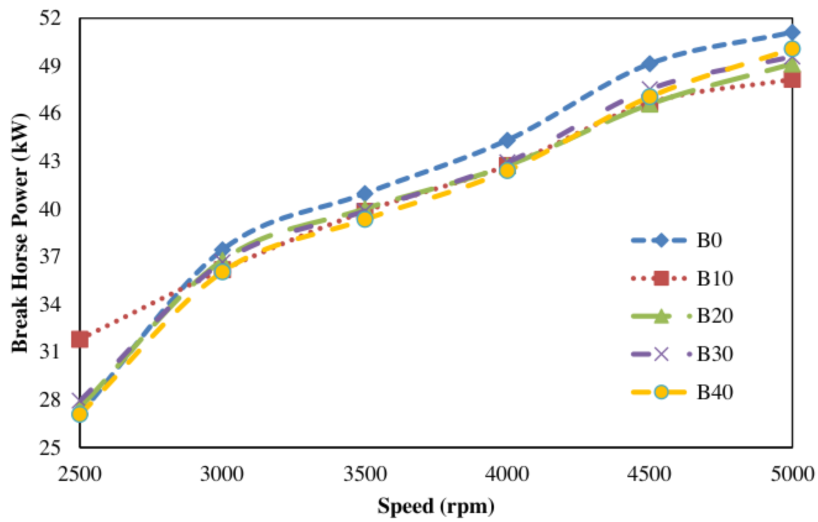

Figure 3. Effects of engine speed to the brake horse power for different diesel blends.

Conclusion

An addition of *C. Pentandra* biodiesel to the diesel fuel affect the engine torque and the break horse power. From the performance test, B0 diesel fuel has generated the highest torque value. After adding a biodiesel in the fuel mixture B10, B20, B30, and B40 the torque produced is decreasing. The torque value is affected by the amount of energy generated from the combustion process. Meanwhile, the amount of energy is strongly influenced by the calorific value of the fuel. The decrease torque value is influenced by the calorific value of biodiesel, the calorific value of biodiesel fuel is smaller when compared to dexlite (B0) where the biodiesel calorific value is 39.74 MJ/kg and the calorific value of dexlite is 44.45 MJ/kg. Based on the average value of produced brake horse power, B0 generated the highest brake horse power. An addition of *C. Pentandra* oil decreases the power output. Compared to the produced torque, it is in accordance with the theory where the output power is influenced by the magnitude of the produced torque.

Acknowledgement

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