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Performance Characteristics of Diesel Engine using Blend of lrvingia Malayana Biodiesel and Cassava Ethanol

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Abstract

This paper investigated the properties of blend of lrvingia Malayana Biodiesel and ethanol and the effect on performance and black smoke of diesel engine. Comparison between diesel, biodiesel, and blend of biodiesel and diesel were also presented. A single cylinder Kubota diesel engine RT- 100 was tested at 1000-1400 rpm and 50% of maximum engine load. The biodiesel and ethanol were blended at ratio of 90:10 (BE10), 80:20 (BE20), and 70:30 (BE30) by volume. Properties of blend, including density, viscosity and the heating value were measured. The experimental results showed that the density and viscosity of the blend was increased, but the heating value was reduced when compared with pure diesel fuel. Brake thermal efficiency of diesel engine operated on blend between biodiesel and ethanol was slightly decreased. However, black smoke as the result from using the proposed blends were reduced when comparing with biodiesel and diesel oil.

Keywords*:* Renewable energy; Heating value; Fuel consumption; Brake Thermal efficiency.

1. Introduction

Currently, the demand of fuel consumption in Thailand has been increased steadily, resulting to the reduction of fossil fuels resource and energy stability. For this reason, the government and relevant departments have been promoting the research and development of renewable energy sources. One approach is the using the local agricultural products as fuel, such as ethanol and biodiesel. That is, ethanol can be produced from production and waste from cane, bagasse, molasses, etc. In the same way, biodiesel can made from crops that are available in Thailand, such as Palm, Jatropha seeds, Sunflower seeds, and Irvingia malayana.

Irvingia malayana is a medium to large deciduous tree with 10-30 m tall that often grow in Northeast. Normally, oil from the seeds is used for cooking, soap and candles. The research about properties of biodiesel from Irvingia malayana, neem, and soybean oil showed that biodiesel have a cetane number higher than diesel but heating value is similar (Nilpueng and Kaewkool [1]). Ethanol which is used as fuel for the engine is a type of alcohol derived from plants produced by the fermentation and distillation to a purity of 95% or higher. Ethanol is composition of oxygen and it needs smaller amount of air to burn completely, resulting the decrease of black smoke. It also found that ethanol has high octane. In the past, most of research studied the use of ethanol as a fuel with gasoline such as E 20 and E 85. However, ethanol is difficult to perform in a diesel engine because it's low cetane number and heating value. Therefore, the using of ethanol as fuel for diesel engine is challenged by researchers.

Vansila [2] mathematically studied the engine performance using diesel blended ethanol. The results of the ethanol blended with diesel in single cylinder four-stroke found that 89.24 % of mixing gave the same power as compared to diesel. Thermal performance of diesel engine using ethanol blended with diesel was decreased slightly.

Kaewkool et al. [3], Nilpueng and Kaewkool [1], Kaewkool et al. [4] studied the properties of biodiesel, i.e. density, viscosity, cetane number, heating value from agricultural products (Irvingia malayana, neem, soybean oil). It was found that biodiesel have a cetane number higher than diesel. Heating value was similar to diesel. They state that biodiesel can be produced from existing agricultural products in the country. Then, it led to the reduction of a petroleum importation.

Thaiyasuit et al. [5] studied the effects of using biodiesel from vegetable oils mixed with ethanol on performance and emissions of diesel engine. Blending of ethanol in diesel with a ratio of 0%, 5%, 10% and 15% were used. The results showed that the heating value and black smoke of biodiesel and ethanol blend was lower than diesel. But the viscosity of blend was higher than diesel.

The performance and emissions of a small diesel engine that used biodiesel blends of ethanol at a ratio 10% (BE10), 30% (BE30), 50%(BE50) was investigated by Thanompongchart [6]. The experiment was performed at speed engine of 1000, 1300, 1600, 1900 and 2000 rpm. Thermal efficiency of the diesel was higher than biodiesel and biodiesel was higher than blend of biodiesel and ethanol. In addition, CO, HC and NOx emissions from biodiesel and ethanol mixing was lower than diesel.

The data from past researches showed that the studies of blend between biodiesel and ethanol as a fuel in a diesel engine was relatively small. A clear understanding and optimum condition for performance and emission of diesel engine when operated on biodiesel is still insufficient. Therefore, the objective of this research is to study the properties of blend between biodiesel and ethanol, i.e. density, viscosity and heating value and the effects of mixing ratio between ethanol and biodiesel on engine performance and emission. Including, brake power, brake specific energy consumption, thermal efficiency and black smoke. The comparison of price between blend and diesel is also presented.

2. Experimental apparatus and procedure

In this section, the detail of experiment is described. It is divided into two main parts: blend oil properties and engine performance as follows:

2.1 Properties of blend oil

Blend oil used in this test is biodiesel from lrvingia Malayana (B100) and ethanol from cassava (E100) as shown in Fig.1. Properties of diesel, biodiesel and ethanol is presented in table 1. To obtain the blend oil, biodiesel and ethanol is directly mixed and stirred in beaker. The volume ratio of biodiesel and ethanol of 90:10 (BE10), 80:20 (BE20), and 70:30 (BE30) is used. Fig.2 shows that biodiesel and ethanol mixed well and color is gradually clear with increasing ethanol. Properties of blend which is measured in this study is density, viscosity and heating value. Density is measured by using digital scale. Capillary tube viscometer and bomb calorimeter (Fig. 3) is used to measure the viscosity and heating value, respectively.

Table 1 Properties of diesel, biodiesel and ethanol

Properties	Diesel	Biodiesel	Ethanol
Low heat Value (kJ/kg)	46,362	37.450	27,921
Cetane number	51.28	57.77	5.97
Density @40ºC (kg/m3)	821.14	880.31	773.52
Viscosity @40ºC (mm^2/s)	3.14	10.67	1.27
% wt Oxygen	0	11.48	34.42
% wt Carbon	85.98	76.42	52.39
% wt Hydrogen	13.87	12.06	13.19

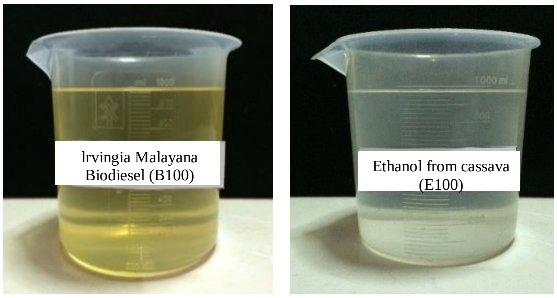

Fig. 1 Biodiesel and ethanol

Fig. 2 Blend of biodiesel and ethanol

Fig. 3 Bomb calorimeter and capillary tube viscometer

2.2 Engine performance

Engine performance and black smoke of blend oil between biodiesel and ethanol was tested by using the experimental apparatus as shown in Fig. 4. It is single cylinder diesel engine test bed (MT 502) manufactured by Essom company limited. It consists of engine, dynamometer, air flow measurement unit (orifice plate, air box, and inclined manometer), fuel consumption measurement unit (fuel tank and measuring cylinder), and smoke meter. Kubota RT100 which was used for agricultural application was tested at speeds of 800 rpm, 1000 rpm, 1200 rpm and 1400 rpm and engine load at 50% of maximum power. Engine specification is presented in table.2. Dynamometer (water brake absorber) was connected to the shaft of the engine. Torque and speed was detected by load cell and speed sensor and displayed by digital indicator. To measure the fuel consumption, the amount of fuel in the measuring cylinder and running time was recorded. Tolerance of measuring cylinder was 1.00 mL. The uncertainty of stopwatch was ±0.01s. Air velocity obtained from air flow measurement unit was calibrated with hot wire anemometer with ± 2.5% accuracy. Measured torque was calibrated from manufacturer with ±5.0% accuracy. Black smoke concentration was measure by Zexel Bosch Smoke Meter (Fig.5).

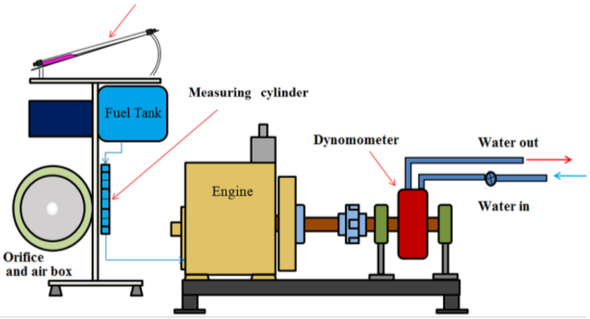

Fig. 4 Experimental apparatus for testing the engine performance.

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Table 2 Technical data of engine

Model	**RT 100 DI**
Type	Diesel engine with water cooling system
Number of piston	1
Dimension of cylinder x stroke (mm)	88 x 90
Piston displacement (cm^3)	547
Maximum power	7.4kW/ 2400rpm
Continuous power	6.6kW/ 2400rpm
Maximum torque	3.4 kg. m/ 1600rpm
Compression ratio	18: 1
Specific fuel consumption (g/kWh)	231

Fig. 5 Black smoke meter

2.3 Data reduction

The experimental data that recorded from this testing is calculated to present and compare in terms of the following parameters.

2.3.1 Engine power

$$P = 2\pi T n / 60 \qquad (1)$$

where P = engine power (W)

T = torque (N-m)

n = engine speed (rpm)

2.3.2 Fuel consumption, Brake-specific fuel consumption (BSFC) and Brake-specific fuel consumption (BSFC)

$$\dot{m}_f = \dot{V}_f \rho_f \qquad (2)$$

$$\mathrm{bsfc} = 3600\dot{m}_f / P \qquad (3)$$

$$\mathrm{bsec} = \sum(\mathrm{bsfc} \times \mathrm{LHV}) \qquad (4)$$

where $\dot{m}_f$ = fuel consumption (kg/s)

$\dot{V}_f$ = volume flow rate of fuel (m^3/s)

ρ_f = density of fuel (kg/m^3)

bsfc = brake-specific fuel consumption (g/kW-h)

bsec = brake-specific energy consumption (MJ/kWh)

LHV = lower heating value (kJ/kg)

2.3.2 Thermal efficiency

$$\eta_{th} = P / Q_f \qquad (5)$$

where η_{th} = thermal efficiency (%)

Q_f = Heat transfer from combustion (kW) which calculated by

$$Q_f = \dot{m}_f LHV \qquad (6)$$

3. Results and discussion

Considering the properties of the blend between biodiesel from irvingia malayana and ethanol from cassava in figure 6 found that density, viscosity and lower heating value of blend are decreased when the ethanol ratio increased. That is, density and lower heating value give a slight decrease (1.25-3.52% and 2.53-7.87%) while viscosity show great reduction (41.6-64.6%) when compared with biodiesel. This is due to the fact that density, viscosity and lower heating value of ethanol is lower than that of biodiesel. Then, all properties of blend are also decreased when ethanol is added.

Considering the relationship between engine speed and brake power in Figure 7, the brake power of the engine increases with increasing engine speed. Also, the increase of ratio of ethanol in blend lead to the reduction of brake power of 11.44%, 14.73%, 18.63% and 23.18% for B100 BE10 BE20 and BE30, respectively, comparing to neat diesel fuel. It can be explained by the fact that cetane number and heating value of biodiesel and blend is lower than conventional diesel. This leads to longer ignition delay and lower heat from combustion. It is also found that these effects are higher when increasing the ethanol ratio.

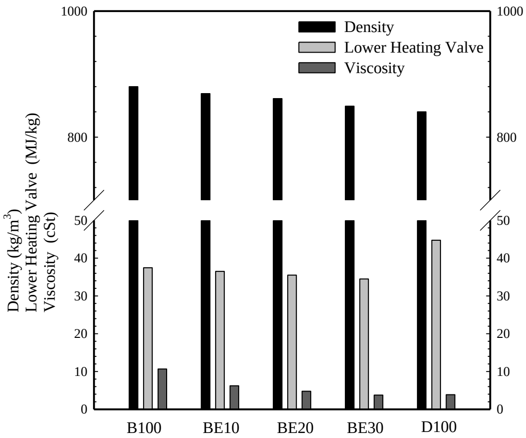

Fig. 6 Properties of diesel, biodiesel and blend

Figure 8 shows the brake specific energy consumption (bsec) of diesel, biodiesel, and blend at different engine speeds. The bsec is gradually reduced when engine speed is increased. The higher ethanol ratio resulted in an increase of bsec, especially, BE20 and BE30. As the result, bsec increased about 1.04%, 2.05%, 3.98%, and 5.56% for B100, BE10, BE20, and BE30, respectively in comparison to pure diesel fuel.

Fig. 9 shows the relation between engine thermal efficiency and engine speed for blend at different ratio. The addition of ethanol ratio in blend results in the reduction of engine thermal efficiency of 1.34%, 2.30%, 3.83% and 5.26% for B100, BE10, BE20, and BE30, respectively, comparing to diesel. It can be explained by the fact that the increase of ethanol ratio lead to the decrease of heating value and thus, brake power. Increasing ethanol in the blend results in decreasing of thermal efficiency.

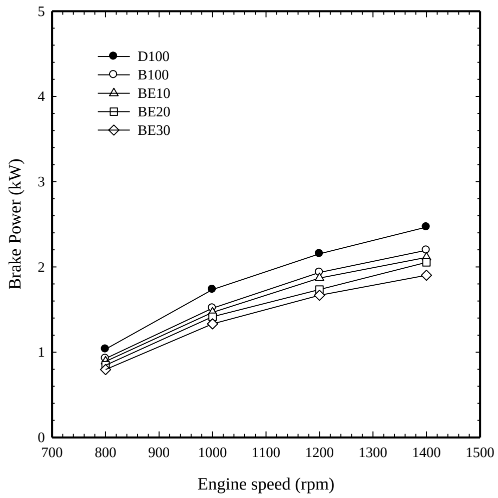

Fig. 7 Relationship between brake power and engine speed

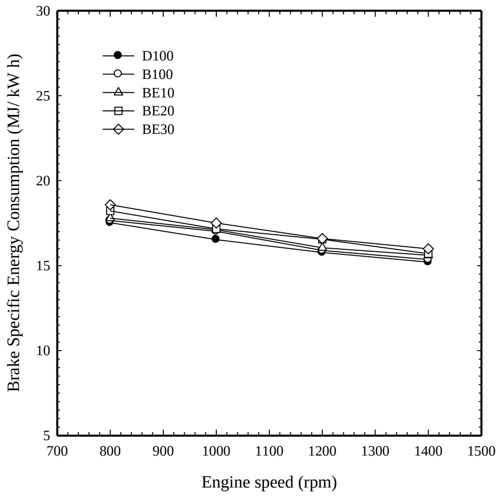

Fig. 8 Relationship between brake specific fuel consumption and engine speed

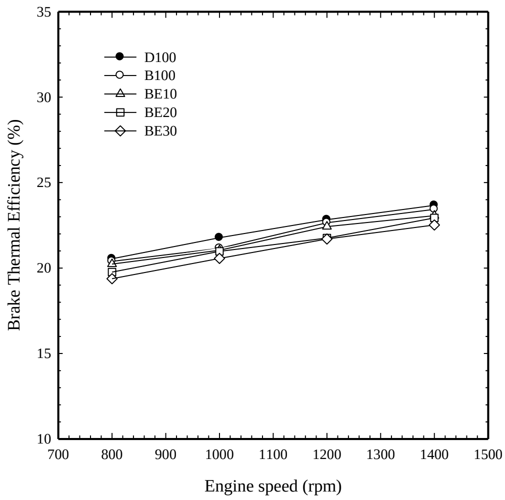

Fig. 9 Relationship between thermal efficiency and engine speed

The black smoke concentration from diesel engine for blends with different ethanol ratio are shown in Fig. 10. It was found that the change of engine speed between 800-1400 rpm has insignificant different on the black smoke concentrations. On the other hand, an increase of the ratio of ethanol resulted in the decrease of black smoke number of 24.87%, 47.03%, 72.34%, and 89.91% for B100, BE10, BE20, and BE30 respectively, when compared to diesel. This is because the fact that oxygen in blend increased when the ratio of ethanol is increased. Oxygen content was contributed to complete combustion by reducing amount of air needed which fuel-rich region decreased. Moreover, reduced viscosity caused by mixing ethanol also enhancing air-fuel mixing as fuel spray had smaller fuel droplet. These combined effects resulted in the significant reduction of black soot concentrations.

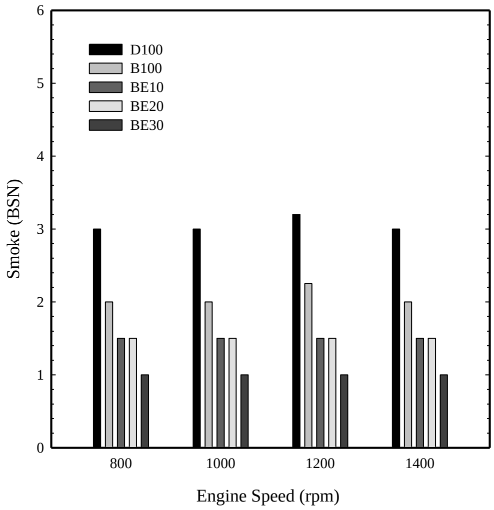

Fig. 10 Relationship between black smoke and engine speed

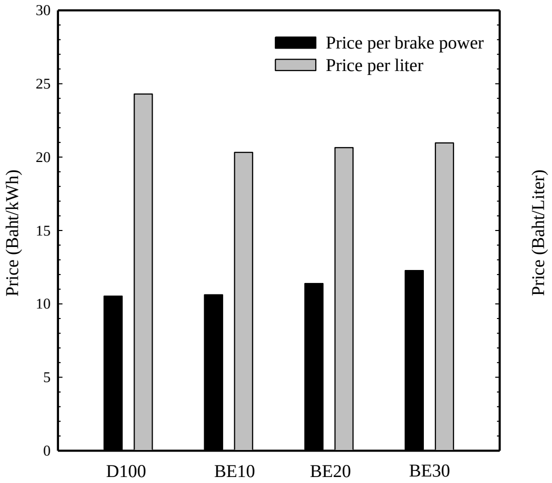

Fig. 11 comparison of price of diesel and blend

Comparison of price between diesel and our proposed blends at different mixing ratio (based on August, 2016) showed that price per liter are 24.30 Baht, 19.98 Baht, 23.40 Baht, 20.32 Baht, 20.66 Baht, and 21.00 Baht for D100, B100, E100, BE10, BE20, and BE30 respectively. Price of blends are substantially lower than neat diesel fuel approxmimately 13.7-16.4 %. However, the price per brake power of blends are sightly higher than diesel.

It is found that blend of BE10 give the best reasonable price compared to conventional diesel.

4. Conclusion

This research studied the properties of blend of biodiesel and ethanol including density, heating value, viscosity and the effects of the blend on engine performance i.e., brake power, brake specific energy consumption, thermal efficiency, and black smoke. The experimental results revealed that the blend of biodiesel and ethanol resulted in lower brake power and thermal efficiency. Although, the blends gave higher brake specific energy consumption when compared to diesel, especially at high ethanol ratio. It was found that thermal efficiency of the engine is reduced between 2.30% - 5.26%. However, the black smoke emissions are greatly reduced with higher ratio of ethanol blend. That is, the black smoke of BE30 was reduced 89.91% as compared to diesel. Overall, the blend of BE10 gave the best reasonable price compared to diesel based on both price per brake power and price per liter while also showed improvement in engine performances.

5. Acknowledgement

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