Journal of Scientific & Industrial Research
Vol. 79, September 2020, pp. 846-849

Performance and Emission Characteristics of a Single-Cylinder Diesel Engine Fueled with Yang (*Dipterocarpus alatus*) Oil

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Received 27 October 2019; revised 27 March 2020; accepted 03 June 2020

The objective of this study was to determine the performance and emission of diesel engine using Yang (*Dipterocarpus alatus*) oil compared with conventional diesel fuel. This test was conducted on a single-cylinder diesel engine at 800, 1200, 1600, 2000, and 2400 rpm, then measured and recorded the values. The experimental results showed that torque, brake power and brake thermal efficiency of the engine using Yang oil showed average increased by 5.22%, 5.38% and 4.27%, respectively and brake specific fuel consumption of the engine using Yang oil showed an average decreased by 6.27% compared with those from diesel. The exhaust gas emission of engine using Yang oil were higher than diesel; CO, CO_2 and NO_x emissions increased slightly by 0.3% Vol., 2.02% Vol. and 18.80 ppm, respectively.

Keywords: BSFC, BTE, Engine performance, Exhaust gas emission

Introduction

For the world will have been facing a fuel energy crisis, there has been research on alternative fuel from plants.[1–6] In the present, there are to bring oil from the yang tree to develop in order to use it to be used as alternativediesel.[7,8] Before using with the engine, they have to be brought through the distillation process for separate only the parts of oil (properties of yang oil as shown in Table 1).[9] For using it within Khon Kaen University (KKU) in Thailand, so that needs to be investigated as to the impact of using yang oil with engines.

Experimental Setup and Methodology

The engine used in this research is a single-cylinder diesel engine. The engine performance test set that is shown as a schematic diagram (in Fig. 1) consists of a CTS–400 Gimatic hydraulic dynamometer, a digital tacho meter, rpm speed meter, a load cells that weigh the oil to measure fuel consumption every 1 minute, an Engine exhaust meter that is a Kane AUTO 4-1 4 Gas analyzer, measuring the amount of carbon monoxide (CO), carbon dioxide (CO_2) and nitric oxides (NO_x) in units of % vol., % vol. and ppm, respectively.

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Testing of the Engine

The engine was installed with the dynamometer, and the measuring device. In first step the sample oil was added to the oil tank and the engine was started. Next, the engine was set at 800 rpm for about 20 minutes. Then it was set to 1500 rpm for 20 minutes, for the engine to be warmed up to reach the stable operating temperature. When the engine had reached the appropriate conditions, the water valve would be opened that to allow water into the dynamometer to increase engine braking. This increases the braking force. The speed of the engine would be reduced according to the increased braking force. When the engine speed was dropping from 2400 to 2000, 1600, 1200, and then 800 rpm which each cycle speed must be less than 10 rpm, the parameters were measured and recorded the speed round, the force acting on the load cell, fuel consumption and exhaust gas emissions (CO, CO_2 and NO_x). In testing, the sample oils were tested 3 times and the various parameter would be calculated for the average values that torque, brake power, brake specific fuel consumption and brake thermal efficiency as the Eqs (1–4), respectively. Finally, the results would be used to find the relationship with the engine speed and compare the results between the yang oil and diesel fuel.

The calculations of torque, brake power, brake specific fuel consumption and brake thermal efficiency are as follows:

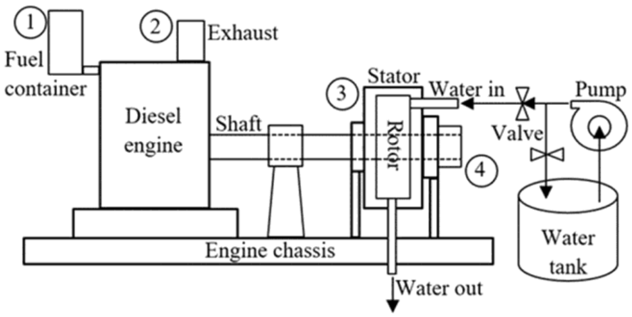

Fig 1 — Schematic diagram of the diesel test engine and its dynamometer; (1) Load cell, (2) Exhaust gas analyzer, (3) Dynamometer, (4) Tachometer

Table 1 — Properties of Yang oil[9]

Property	Test method	Standard Value	Yang-Na oil
Heating Value, kJ/kg	ASTM D240	—	45,188
Specific Gravity@60F, kg/m^3	ASTM D1298	0.81- 0.87	0.92
Cetane Index	ASTM D976	>50	27
Viscosity@40ºC, cSt	ASTM D445	1.8-4.1	4.7
Pour Point, ºC	ASTM D97	<10	< −39
Sulfur content, %wt	ASTM D2622	<0.005	0.000
Copper Strip Corrosion	ASTM D130	< No.1	No.1
Oxidation stability, g/m^3	ASTM D2274	<25	25
Carbon Residue, %wt	ASTM D189	<0.05	0.00
Water, %wt	EN ISO 12937	< 300	270
Ash %wt	ASTM D482	<0.01	0.0
Flash Point, ºC	ASTM D93	>52	104
Distillation, ºC	ASTM D86	<357	257
Polycyclic Aromatic Hydrocarbons, %wt	ASTM D2425	<11	1
Intensity	ASTM D1500	<4.0	1.5

Torque (T) : The equation for torque of engine (in N.m.) is determined as follows;

$$T = F \times R \quad \ldots (1)$$

Where F is the force acting on the load cell (N), and R is the distance from the center of the dynamo to the force measurement point (m)

Brake power (P_b) : The equation for P_b (in kW) is determined as follows;

$$P_b = \frac{2\pi\omega T}{(1000)} \quad \ldots (2)$$

Where ω is angular velocity in rps.

Brake specific fuel consumption (*bsfc*): The equation for *bsfc* (in kg/kW–h) is determined as follows;

$$bsfc = \frac{\dot{m}_f}{P_b} \quad \ldots (3)$$

Where $\dot{m}_f$ is the fuel consumption in kg/h.

Brake thermal efficiency (η_{bt}): The equation for η_{bt} (in %) is determined as follows;

$$\eta_{bt} = \frac{P_b \times 3600}{\dot{m}_f \times Q_{LHV}} \times 100 \quad \ldots (4)$$

Where η_{bt} is brake thermal efficiency (%), and Q_{LHV} is lower heating value of fuel in kJ/kg.

Results and Discussion

The values of torque, brake power, brake specific fuel consumption, brake thermal efficiency and CO, CO_2 and NO_x exhaust emissions as shown in Table 2.

Table 2 — Experimentation results of an engine fueled with diesel and yang oil

Engine speed (rpm)	Average Torque (N-m)	Average Brake power (kW)	Average BSFC (kg/kW-hr)	Average η_{th} (%)	Average CO (% Vol)	Average CO_2 (% Vol)	Average NO_x (ppm)
			Diesel				
800	22.89	1.92	0.34	23.96	0.53	10.50	79.00
1200	25.61	3.21	0.30	26.72	0.12	10.40	105.00
1600	27.11	4.54	0.29	27.79	0.07	9.80	132.00
2000	26.08	5.45	0.30	26.75	0.06	8.50	149.00
2400	24.16	6.09	0.33	24.88	0.05	5.90	154.00
Average	25.17	4.24	0.31	26.02	0.17	9.02	123.80
			Yang oil				
800	23.90	2.04	0.31	25.42	1.14	11.70	99.00
1200	27.13	3.42	0.29	27.56	0.67	11.70	128.00
1600	28.73	4.79	0.28	28.42	0.31	11.40	154.00
2000	27.90	5.84	0.29	27.84	0.15	10.90	165.00
2400	25.11	6.32	0.30	26.66	0.09	9.50	167.00
Average	26.55	4.48	0.29	27.18	0.47	11.04	142.60
Difference	1.39	0.24	−0.02	1.16	0.31	2.02	18.80

Engine Performance

The test results show that the torque tends to increase as the speed increases which has a maximum value of 1600 rpm and then decreases when the speed is higher than the maximum speed. At low speed, the less vacuum in cylinder is causing the oil to produce lower amount of vapor, resulting in incomplete combustion and lower torque.[4] At high speed, the cylinder has lower volume efficiency and increased mechanical loss causing the torque to drop.[5] The maximum torque of the engine with diesel fuel and yang oil was 27.11 N.m and 28.73 N.m, respectively. The average torque of the engine using yang oil was 5.22% higher than diesel oil

Brake power tends to had constant increase with speed of engine directly until 1600 rpm. At speed 2000–2400 rpm, break power had slight increase due to brake power loss from friction.[6] The maximum brake power of diesel fuel and yang oil were 6.09 kW and 6.32 kW, respectively. The average brake power of the engine using yang oil was 5.38% higher than diesel oil.

Brake specific fuel consumption gives inverse variation with speed until 1600 rpm and gives direct variation at higher speed. Since at lower speed, engine gives longer cycle time than higher speed there is more heat loss at cylinder wall and combustion chamber, so this cause high brake specific fuel consumption.[10] When speed is higher than moderate speed, brake specific fuel consumption tend to be even higher due to increase of friction.[11] The minimum brake specific fuel consumption of diesel fuel and yang oil were 0.29 kg/kW-hr and 0.28 kg/kW-hr, respectively. The average brake specific fuel consumption of the engine using yang oil was 6.27% lower than diesel oil.

Brake thermal efficiency has direct variation with speed until 1600 rpm and tends to get lower at higher speed. Brake thermal efficiency also has direct relation with brake specific fuel consumption. Poor brake thermal efficiency will happen since incomplete combustion occurred at low speed[11] including friction loss and mechanical loss at high speed.[12–14] The maximum brake thermal efficiency of diesel fuel and yang oil were 31.89 % and 28.42%, respectively. The average thermal efficiency of the engine using yang oil was 4.27% higher than diesel oil.

Exhaust gas emission

Carbon monoxide emission decreases as speed get higher. Since yang oil is more viscous than diesel, this make atomization of injected oil become poor and cause poor combustion efficiency. Moreover, carbon content in fuel also affects CO emission. Carbon monoxide emission of yang oil gives higher value as yang oil contains higher carbon than diesel. The average CO emissions of diesel fuel and yang oil were 0.17 % Vol and 0.47 % Vol, respectively.

Carbon dioxide emission decreases with increasing speed. The same as CO emission, yang oil contain more carbon than diesel so this causes CO_2 emission of yang oil to be higher. The average CO_2 emissions of diesel fuel and yang oil were 9.02 % Vol and 11.04 % Vol, respectively.

Nitrogen oxides emission increase as speed get higher, since the main factor of NO_x emission is combustion temperature of fuel. As combustion temperature of yang oil was higher than diesel so this cause yang oil to emit more NO_x. The average NO_x emissions of diesel fuel and yang oil were 123.80 ppm and 142.60 ppm, respectively.

Conclusions

The experimental results of the single-cylinder diesel engine fueled with yang oil compared with diesel fuel showed the following:

(i) Yang oil had a 5.22% average increase in the torque, a 5.38% average increase in the brake power, a 6.27% average decrease in the brake specific fuel consumption and a 4.27% average increase in the brake thermal efficiency.

(ii) The CO, CO_2 and NO_x emissions from yang oil is slightly higher than diesel.

These results indicate that yang oil can be used without any modification of the single-cylinder diesel engine and as an alternative and environment friendly fuel. The yang oil use can reduce the KKU's consumption of diesel that consumes approximately 175 liters/month.

Acknowledgement:

This study is funded for research from Khon Kaen University. Thanks to the public utility, energy and environment management division, research instrument center of Khon Kaen University and Thammasat University Pattaya Campus.

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