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Performance and Emission of Small Diesel Engine Using Diesel-Crude Palm Oil-Water Emulsion as Fuel

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Abstract

Diesel and crude palm oil (CPO) emulsion was drop-in replaced of diesel oil in a small diesel engine to test the engine performance and emission. In the study, the compositions of diesel/CPO/water of 95/0/5, 90/0/10, 90/5/5, 85/5/10, 85/10/5 and 80/10/10 by volume were used in a four-stroke single cylinder diesel engine having a pre-combustion chamber. The engine speed was in a range of 1000 – 2000 rpm.

From the results, it could be found that the torque and the engine power for the emulsion of 90/5/5 were close to those of from the diesel oil and the performance were poorer when the percentages of CPO and water were increased. The specific fuel consumption of the emulsified oil with the composition of 90/5/5 was quite close to that of the diesel oil at low engine speed and higher consumption was needed with higher amount of CPO and water in the emulsion due to lower heating value in the emulsion. The emissions in terms of CO, NO_x and black smoke for the emulsified oil could be reduced significantly. After 200h of the operation, the wear and the physical corrosions in the engine components for the emulsified fuel of 90/5/5 composition are not much different from those for the diesel oil.

Key words: Palm–diesel emulsion; Diesel engine performance; Emission

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INTRODUCTION

Vegetable oil could be blended with diesel oil in a proper composition and it could be used to run diesel engine. In Thailand, there were some studies reported the results of diesel oil directly blended with crude palm oil (CPO) for running in diesel engines. The composition of CPO should not exceed 20% by volume and the recommended one was 10% by volume (Wibulswas, 2000). However, since the chemical and physical properties of the vegetable oil are quite different from those of the diesel, especially the viscosity which is 9-10 times of the diesel oil then the atomization of the fuel droplets and the fuel volatility are poorer than those of the diesel oil which results in poorer combustion performance.

One technique to reduce the blended fuel viscosity is to mix water into the fuel in a form of emulsion.

Lin and Wang (2004) studied a small single cylinder diesel engine performance when diesel/water emulsion was used as fuel. Span-80 was a surfactant for the emulsion. The engine power was less than that with the diesel oil and the performance was poorer with the percentage of water in the emulsion but the quality of the exhaust gas is better. The engine could not operate when the amount of water reached 20% by volume. Abu-Zaid (2004) also used diesel/water emulsion with water compositions of 0, 5, 10, 15 and 20% by volume to run a 659 cc direct injection diesel engine. Span 80 and Tween 80 were surfactants to form the emulsion. More complete combustion was found for the emulsified oil than that for the diesel oil and the temperature of the exhaust gas was lower. The torque and the engine power from the emulsified oil were slightly different from that from the diesel oil but the specific fuel consumption was higher with the amount of water composition. Lin and Lin (2007a; 2007b) used emulsified oil from diesel blended with trans-estered biodiesel from soybean. Span 80 and Tween 80 were surfactants. The emulsified oil was taken as fuel in a 4 cylinders, 4 strokes direct ignition diesel engine. Since the heating value of the emulsified oil was lower than that of the standard diesel oil, therefore, the specific fuel consumption of the emulsified oil was higher but CO and NO_x in the exhaust gas were lower.

In this study, diesel oil and crude palm oil(CPO) in a form of emulsion with compositions of diesel/CPO/water of 95/0/5, 90/0/10, 90/5/5, 85/5/10, 85/10/5 and 80/10/10 by volume were taken as fuels in a four-stroke single cylinder diesel engine having a pre-combustion chamber. The engine speed was taken in a range of 1000–2000 rpm. The engine performances and the emissions were considered. Moreover, the wear and the physical corrosions in the engine components for the emulsified oil were also discussed.

1. EXPERIMENTAL TEST

1.1 Emulsified Oil

An emulsion is a mixture of two or more immiscible liquids which could be merged by some kind of surfactant. One liquid (the dispersed phase) is dispersed in the others (the continuous phase).

The surfactant is also called emulsifier and in this study the surfactant is 1% by volume of Sorbitan monooleate ($C_{24}H_{44}O_6$). The blending was performed by agitating the mixture having 1,000 liter in a tank with an agitator speed of 1,500 rpm for 10 minutes. Figure 1 shows the structure of emulsified oil and Figure 2 shows the stability of the emulsion after blending. The heating value (LHV) and other properties of the emulsified oils are also shown in Table 1.

Table 1
Physical Properties of Fuels

Fuel	Heating Value (kJ/kg)	Density (kg/m^3)	Viscosity (cst @ 40℃)
Diesel	45,297	826	2.93
Diesel/Water (95/5)	44,274	832	2.98
Diesel/Water (90/10)	42,538	846	3.03
Diesel/CPO/water (90/5/5)	43,249	838	3.96
Diesel/CPO/water (85/5/10)	41,850	844	3.52
Diesel/CPO/water (85/10/5)	42,394	842	4.48
Diesel/Palm/water (80/10/10)	41,611	848	4.14

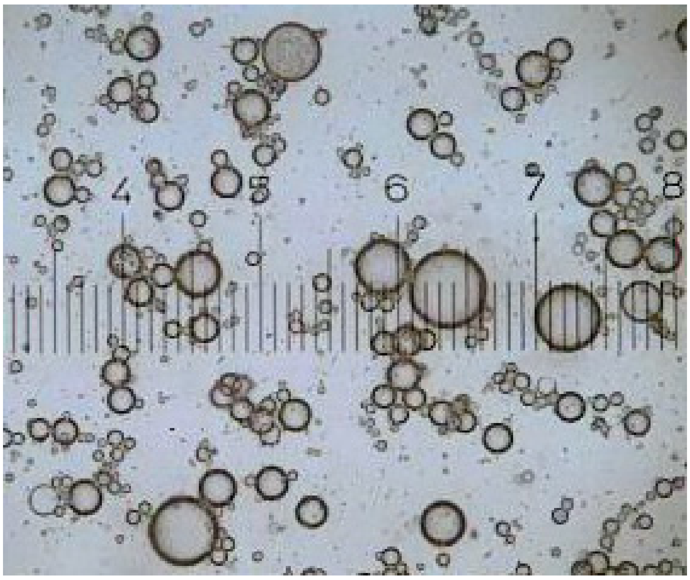


Figure 1
The Structure of Emulsified Oil (Diesel/CPO/Water 90/5/5, the Magnification of Eye Piece is 10X)

a. 0 min left. b. 20 min left. c. 60 min left. d.1 day left.

Figure 2
The Stability of the Emulsion After Blending (The Composition was Diesel/CPO/Water 90/5/5)

In general, the heating value of the blended diesel/CPO was slightly lower than that of the diesel oil but the viscosity of the blended oil was higher. When water was merged with the blended oil in the form of emulsion, the viscosity was less with the content of water.

Surfactant was used to merge water with oil in a form of emulsion as shown in Figure 1. The water droplets of about 6 micron were coated with small oil droplets. However, there was instability in mixing after a period of time. It could be noted that there were some deposits after time lapse about 20 min after mixing. Anyhow, the emulsion could be recovered immediately after shaking the mixture. Figure 2 shows the stability of the emulsion after blending.

1.2 Engine Test and Emissions

A four-stroke single cylinder diesel engine having a precombustion chamber with a maximum power of 7.5 hp at 2,200 rpm and the cylinder volume of 437 cm^3 was running with the tested fuels. The engine specification is shown in Table 2.

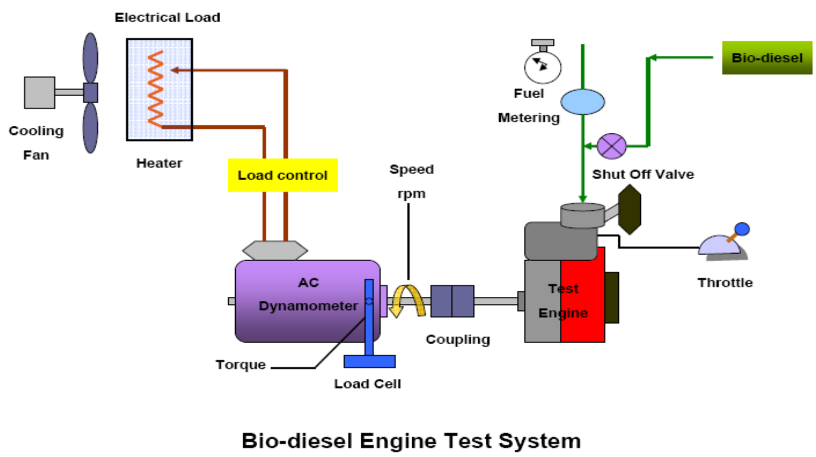


Figure 3
The Engine Test Bed

The engine was coupling with an a.c. dynamometer of which the electrical load could be adjusted. The engine torque could be directly estimated from the force measured by a digital load cell and the load cell arm. The engine speed was measured with a digital proximity sensor (accuracy 0.03 % F.S.) and the fuel consumption was directly calculated from the difference of oil level in an oil-feeding cylinder and the operating time. The engine test bed is shown in Figure 3.

Table 2
The Engine Specification for Diesel Fuel

Engine Type	4-stroke, horizontal cylinder with water cooling
No. of cylinder	1 with a precombustion chamber
Cylinder Size x Stroke Length (mm x mm)	80 x 87
Cylinder Capacity (liter)	0.437
Peak Power	7.5 hp or 5.52 kW at 2,200 rpm
Max. Torque	2.70 kg-m at 1600 rpm
Specific Fuel Consumption	195
Compression Ratio	23 : 1
Degree of Oil Injection (degree)	13 degree (before top dead center)

Oil Injection Pressure (kg/cm^2)	

%RH	120	0 to 100%

The engine power and the specific fuel consumption could be evaluated as follows:

The engine torque (N m) could be calculated from

$$T = F \cdot r, \quad (1)$$

F is force (N) which could be read directly from the load cell and r is the radius arm of the load cell (m).

The engine power, P (kW), could be calculated by

$$P = \frac{2 \cdot \pi \cdot T \cdot N}{60 \times 1000} \quad (2)$$

N is engine speed (rpm).

The specific fuel consumption (g/kW·hr) could be calculated by

$$sfc = \frac{m_f^{'}}{P} \quad (3)$$

m'_f is mass rate of fuel consumption (g/hr).

The engine gas emission could be read directly from a flue gas analyzer TESTO 350 XL of which CO (ppm) , NO_x (ppm) were main items in this study. The details of the emissions and the measuring range of the instrument are shown in Table 3.

Table 3
Details of Emissions and Their Measuring Range of Testo 350 XL

Sensor	Measurement Range
O_2	0 to 25 vol. %
CO	0 to 10,000 ppm.
CO_2	0 to CO_2 max.
NO	0 to 3,000 ppm.
NO_2	0 to 500 ppm.
SO_2	0 to 5,000 ppm.
H_2	0 to 300 ppm.
C_xH_y	0 to 4 Vol. %
Pressure	+/- 200 kPa.
Velocity	40 m/s.
Temperature	-40 to 1,200 °C
Efficiency	0 to 120 %

Black smoke could be read directly with a Hermann DO 285 Opacity Meter. The tested engine speed was varied from 1000 rpm up to 2000 rpm with a step change of 200 rpm. At each step, the engine was maintained steadily before data measurement. Each experiment was performed 5 times and the average value was undertaken.

2. RESULTS AND DISCUSSIONS

2.1 Engine Performances and Emissions

Figs. 4 and 5 show the engine torques and engine powers when different types of fuels are used at various engine speeds. For diesel oil, when 5 % of water was mixed with (95/0/5), the engine torque and the engine power were slightly lower than those without water (100 % diesel oil) at low engine speed. But when the engine speed was over 1400 rpm, the performances were less than those of diesel oil significantly due to the lower heating value with the amount of water mixing. Similar results were found with the emulsions of diesel/CPO/water. For diesel/CPO/water at 90/5/5, the engine performances were close to those of diesel/water at 95/0/5. The engine torques and the engine performances dropped with the percentages of CPO or water in the emulsions. It could be noted that the engine could run steadily when the percentages of CPO and water were not over 10 and 10 %, respectively.

Figure 6 shows the specific fuel consumption of the engine with the tested fuels which generally increases with the engine speed. The engine with 100 % diesel oil showed the best performance due to its highest heating value. For diesel/CPO/water at 90/5/5, the specific fuel consumption was close to the diesel mixed with 5 % water at low engine speed but when the speed was higher than 1400 rpm, more specific fuel consumption was higher due to its lower heating value. Again, when the percentages of CPO and water were higher in the emulsion, higher specific fuel consumptions were needed.

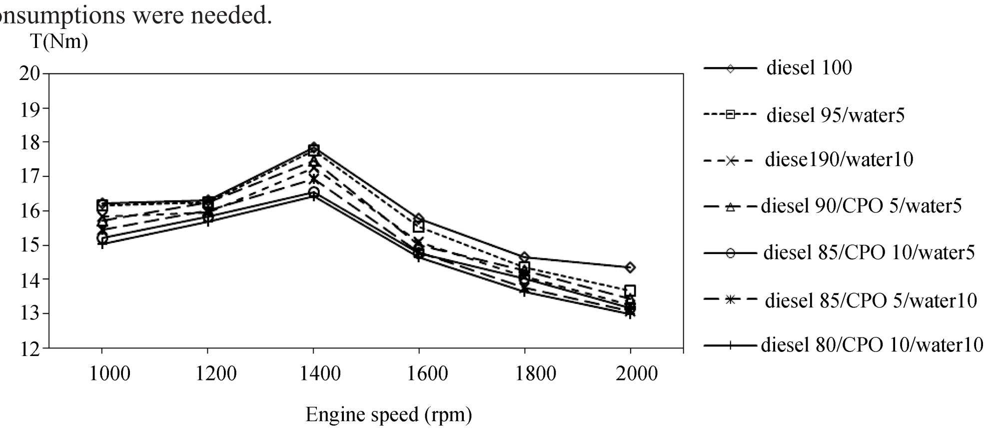


Figure 4

Engine Torque at Different Engine Speeds

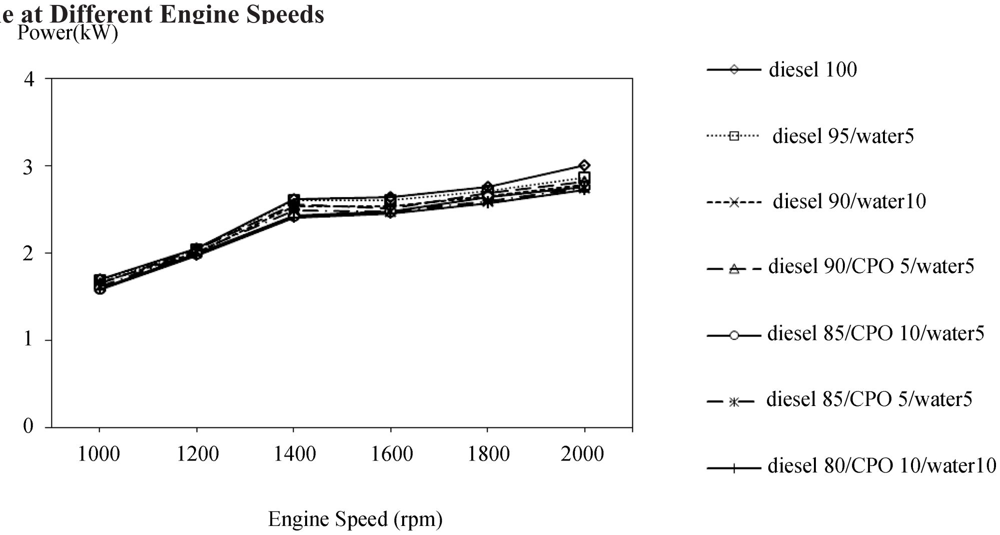


Figure 5
Engine Power at Different Engine Speeds

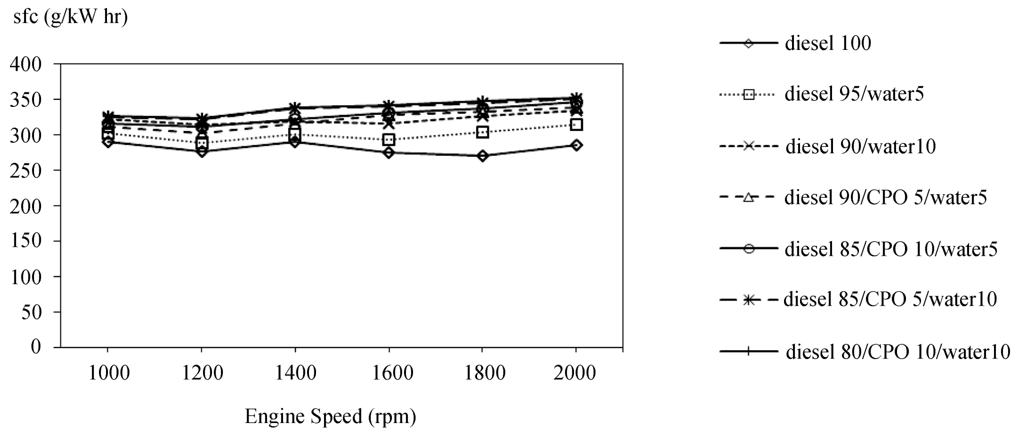


Figure 6
Specific Fuel Consumption at Different Engine Speeds

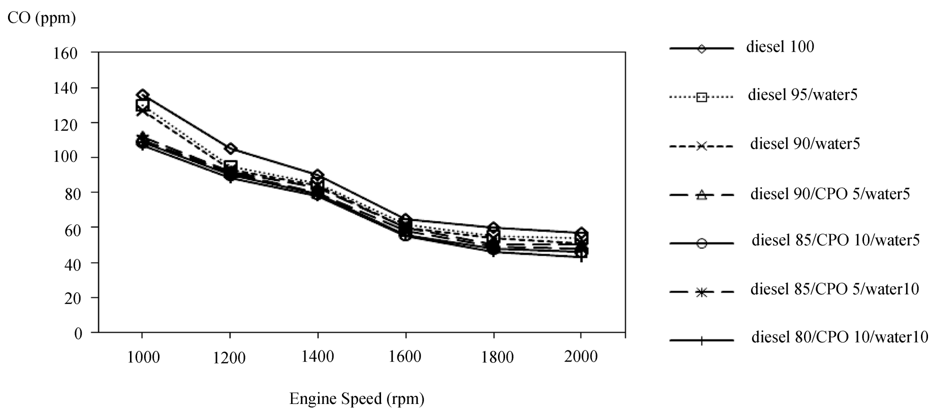


Figure 7
CO Emission at Different Engine Speeds

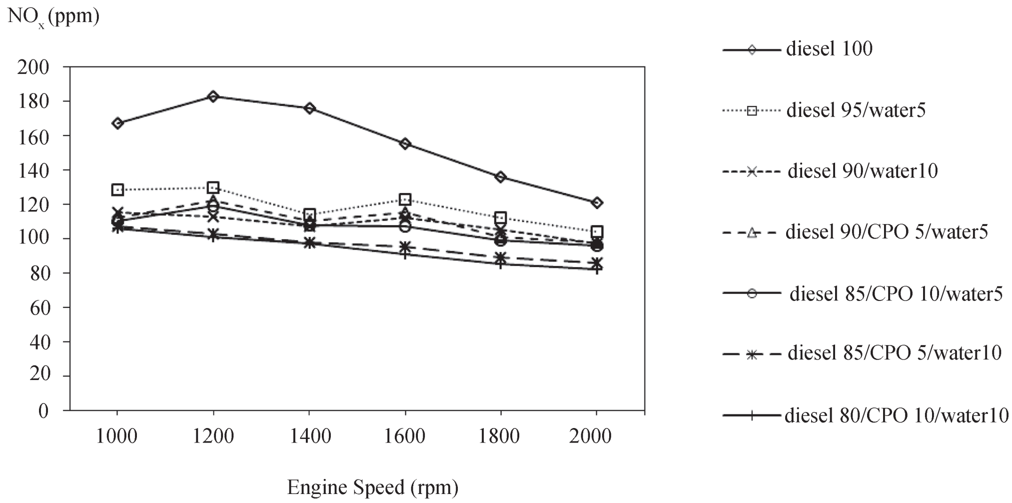


Figure 8
NO_x Emission at Different Engine Speeds

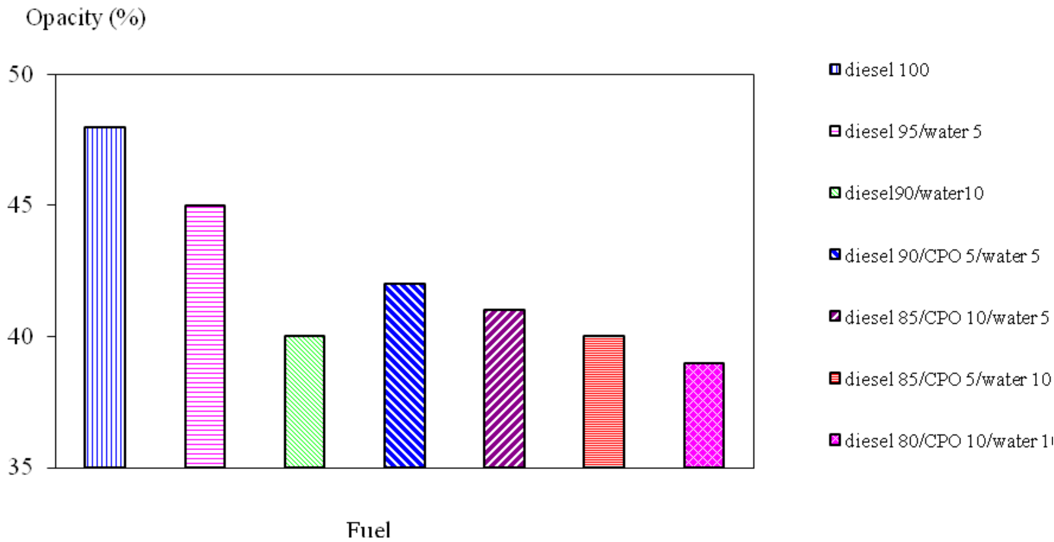


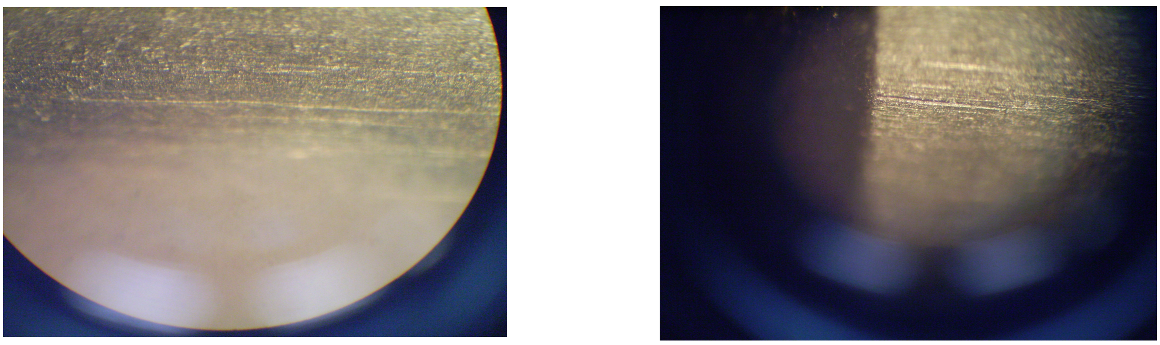
Figure 9
Black Smoke of Engine with Different Oil Compositions

Figs. 7 and 8 show CO and NO_x emissions of the engine with different tested fuels. It could be seen that the diesel/CPO/water emulsion gave lowest emissions followed by the diesel/water emulsion. Figure 9 shows the results of the black smoke from the engine. The opacity of the black smoke from diesel oil was 48 % while those from diesel/water emulsion and diesel/CPO/water emulsion were 40-45 % and 38-42 %, respectively. Therefore, it could be noted that the emulsion could reduce the emissions of the engine significantly but higher specific fuel consumptions were needed.

Figs. 10-12 show the wear effects on some engine parts when the fuel is diesel/CPO/water at 90/5/5 composition. The engine operation was 200 h and the considered engine parts were engine piston and piston of fuel oil pump. It could be seen that the wears of these components were similar to those of diesel oil and the engine piston was cleaner from that with the diesel oil.

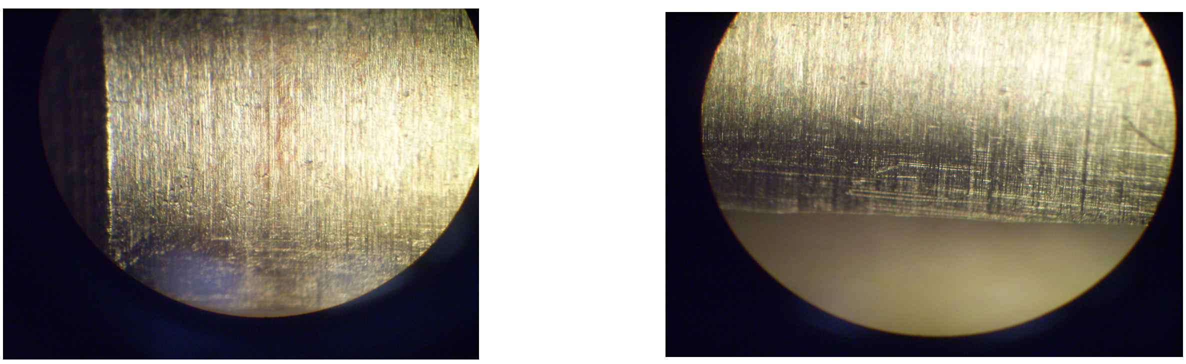
Diesel **Palm-Diesel Emulsion**

Figure 10
Wear at the Engine Piston for the Fuel Oil and the Emulsified Diesel/CPO/Water of 90/5/5 After 200 h Operation



Diesel Palm-Diesel Emulsion

Figure 11
Wear at the Needle Injection of Fuel Pump for the Fuel Oil and the Emulsified Diesel/CPO/Water of 90/5/5 After 200 h Operation



Diesel **Palm-Diesel Emulsion**

Figure 12
Wear at the Piston of Oil Pump for the Fuel Oil and the Emulsified Diesel/CPO/Water of 90/5/5 After 200 h Operation

CONCLUSIONS

Higher viscosity and low heating value of emulsified blended oil of diesel/CPO were found with higher content of CPO compared with those of diesel oil. Higher content of water also reduced viscosity and heating value. With suitable composition of the diesel/CPO/water emulsion as fuel in the tested diesel engine, such as 90/5/5 composition, the engine power and the engine torque were close to that with diesel oil and the specific fuel consumption was slightly higher than that of the diesel oil but the emissions in terms of CO, NO_x and black smoke were less significantly. Moreover, the wears in some engine parts were found to be similar with those with the diesel oil after 200 h operation.

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REFERENCES

[1] Abu-Zaid, M. (2004). Performance of Single Cylinder, Direct Injection Diesel Engine Using Water Fuel Emulsions. *Energy Conversion and Management*, *45*, 697-705. DOI:10.1016/S0196-8904(03)00179-1.

[2] Lin, C.Y, & Lin, H.A. (2007a). Effects of Emulsification Variables on Fuel Properties of Two- and Three-Phase Biodiesel Emulsions. *Fuel*, *86*(1–2), 210-217. DOI: 10.1016/j.fuel.2006.06.007.

[3] Lin C.Y., & Lin, H.A. (2007b). Engine Performance and Emission Characteristics of a Three-Phase Emulsion of Biodiesel Produced by Peroxidation. *Fuel Processing Technology*, *88*(1), 35-41. DOI: 10.1016/j.fuproc.2006.07.008.

[4] Lin, C.Y., & Wang, K.H. (2004). Effects of a Combustion Improver on Diesel Engine Performance and Emission Characteristics When Using Three-Phase Emulsions as an Alternative Fuel. *Energy & Fuels*, *18*(2), 477-484. DOI: 10.1021/ef0300848.

[5] Wibulswas, P., Winyachompunart, B., & Tiansuwan, J. (2000). *Proceedings of the World Renewable Energy Congress VI: Renewables-Energy for the 21st Century, Brighton, UK*.

