COMBUSTION CHARACTERISTICS FOR SMALL DIESEL ENGINE BY USING EMULSIFIED BLEND FUELS OF VEGETABLE OIL AND LIGHT OIL

Tadashige Kawakami

Faculty of Science and Engineering Hosei University
Kajino-cho, Koganei, Tokyo 184-8584 Japan
e-mail: kawakami@hosei.ac.jp

Abstract

The paper is focusing on combustion characteristics for small diesel engine by using emulsified blend fuels of vegetable oil and light oil. Target is to achieve low emissions and low fuel consumption for internal combustion engines. The fuels used in this study are light oil, blend fuels [light oil + coconut oil, light oil + palm oil], and emulsified fuels [light oil + water, blend fuels + water]. Mean increasing rate of pressure is calculated from the value which subtracted initial pressure from maximum burning pressure divided by total burning time. The mean increasing ratio of pressure is calculated from the value which subtracted initial pressure from maximum burning pressure divided by the total burning time. The emissions in exhaust gas are measured with an analyzer of exhaust gas. The data of 30 tests for each engine revolutions were averaged arithmetically. Experimental approach and results have been presented by details.

The main conclusions are as follows: it is possible to control the combustion behaviour by using blend fuels and emulsified blend fuels for small diesel engine; the maximum burning pressure of emulsified blend fuels increases at low engine speed; the CO emission of blend fuels is smaller than that of light oil; the NOX emission of emulsified coconut blend fuel and emulsified palm blend fuel is smaller than that of light oil; the CO emission of emulsified Coconut-Palm blend fuel is equal to that of light oil at low engine speed.

Keywords*: combustion characteristics, small diesel engine, ecology energy*

1. Introduction

Nowadays, the global environmental problems and the global energy problems become very serious. Internal combustion engines are main causes of these problems. So it is necessary to achieve low emissions and low fuel consumption for internal combustion engines. Especially, in automotive diesel engines, low-particulate and low-NO_X emissions are very much needed by using blend fuels and emulsified hydrocarbon fuels. For example, several techniques were developed for reduction of NO_x, CO, HC emissions from the diesel engines such as EGR (Exhaust gas recirculation), lean combustion and Homogeneous Charge Compression Ignition (HCCI) [1-7].

As the first step in this study, experiments have been carried out to determine the influence on combustion characteristics and exhaust emissions for small diesel engines by using emulsified vegetable-light oil. The combustion behaviours, such as maximum burning pressure, total burning time, mean increasing ratio of pressure, emissions in exhaust gas (NO_X, CO, CO_2, O_2 concentration), are observed. The fuels used in this study are light oil, blend fuels [light oil + coconut oil, light oil + palm oil], and emulsified fuels [light oil + water, blend fuels + water]. Mixing rate is varied by the changing volume of coconut oil and palm oil and the mass of water in the fuels. The maximum burning pressure and total burning time are observed by measuring the pressure in the cylinder with piezoelectric pressure transducer. The mean increasing ratio of pressure is calculated from the value which subtracted initial pressure from maximum burning pressure divided by the total burning time. The emissions in exhaust gas are measured with an analyzer of exhaust gas. The data of 30 tests for each engine revolutions were averaged arithmetically.

2. Experimental Set-up

Figure 1 shows the experimental set up employed in this study. It consists of a small diesel engines (Yanmar Co. L40A:199cc 4stroke) and an analyzer of exhaust gas (Shimazu Co. NOA-7000 and CGT-7000, NOx:Chemiluminesence, CO and CO_2: NDIR, O_2:Zirconia). Table 1 shows the engine specifications of the diesel engine in this study. The pressure history in the cylinder was measured with piezo electric transducer (Kistler, type 6052B) attached at the engine head for both engines. Mean increasing rate of pressure is calculated from the value which subtracted initial pressure from maximum burning pressure divided by total burning time.

The fuels used in this study are light oil (Standard),coconut oil and palm oil:[CH2(OCOR1)CH (OCOR2)CH(OCOR), R1~R3:Higher aliphatic hydrocarbon], blend fuels[light oil+Coconut oil] and water emulsified blend fuels.

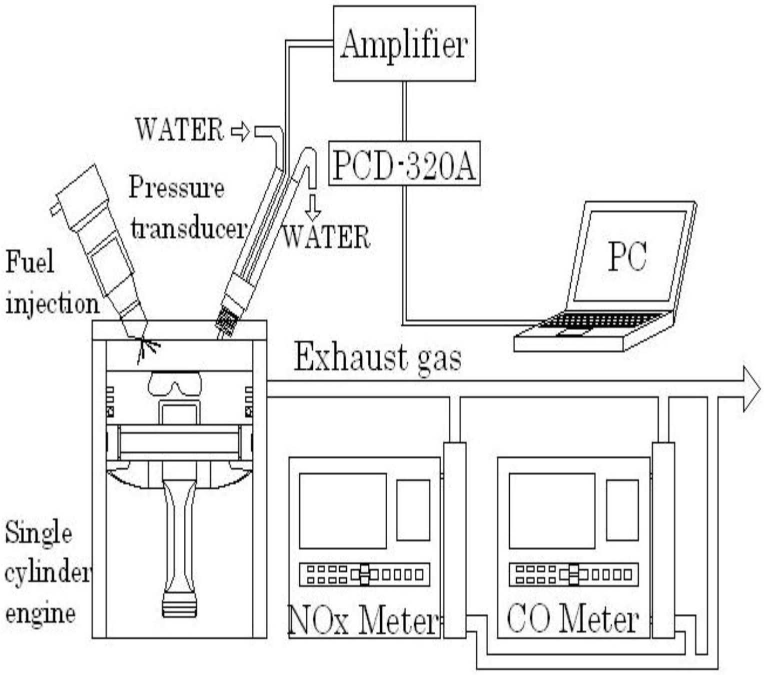

Fig. 1 Experimental device

Tab. 1. Engine specifications

Engine type	L40A 4stroke cycle diesel engine
Combustion system	Direct injection
Cooling system	Air-cooling
Number of cylinder	1
Bore*Stroke	68.0mm*55mm
Displacement	199cc
Valve system	OHV
Injection pressure	19.6MPa
Compression ratio	20.0
Maximum output	3.1kw/3600rpm

3. Results and Discussion

Figure 2 shows the maximum burning pressure against engine speed as a function of fuel properties without engine load. In this experiment, six type blend fuels with light oil are used:

where, for example:

- Coco 10% : 90vol% light oil+10vol% coconut oil,
- Palm 30% :70vol% light oil+30vol% palm oil.

As can be seen from this figure, for the six type blend fuels, the maximum burning pressures are smaller than that of light oil. It is courses by the difference of the net calorific value of light oil and coconut oil or palm oil. And for all blend fuels, the maximum burning pressure increases with increasing the ratio of volume of coconut oil or palm oil at same kind fuels. It is explained that the influence of oxygen in vegetable oil.

Figure 3 shows the maximum burning pressure against engine speed for emulsified fuels. From this figure it can be seen that the almost maximum burning pressure are smaller than that of light oil without the low engine speed. It is caused by the latent heat of water. It is interesting facts that for Palm20%-W9.1 and Palm30%-W9.1% the maximum burning pressures are almost same for light oil at the low engine speed. This fact may be explained by considering the dispersion of fine daughter droplets and increasing turbulence in the combustion chamber caused by micro-explosions for difference boiling points in the droplet components.

Figure 4 shows the CO emissions against engine speed as a function of fuel properties without engine load. As can be seen from this figure, for all the blend fuels, the CO emissions are smaller than that of light oil. It is causes by the influence of oxygen in the vegetable oil, that is the CO changed the CO2 by using the oxygen. Furthermore, the difference of amount of CO emissions is bigger at higher engine speed region than that of lower engine speed region.

Figure 5 shows the CO emissions against engine speed for Coconut oil and Palm oil blend fuels. Where, the Coco10%-Palm 10% symbol means the light oil 80vol%, Coconut oil 10% and Palm oil 10vol%. From this figure it can be seen that, all the two kind of blend fuels, the CO emissions are smaller than that of light oil at any engine speed. And the decreasing ratios are bigger according to the increasing of Coconut oil volume. It is explained that the O_2 content percentage of Coconut oil is bigger than that of Palm oil.

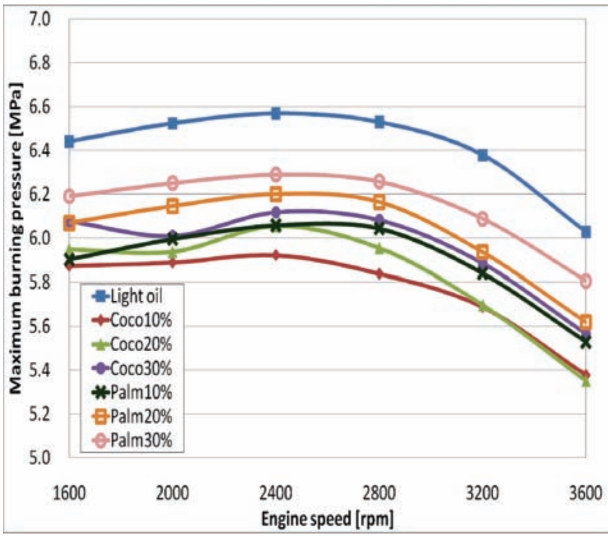

Fig. 2 Maximum burning pressure (Blend fuels)

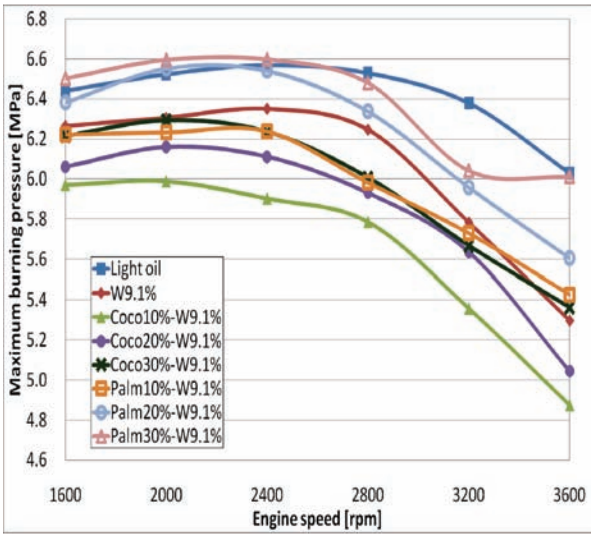

Fig. 3. Maximum burning pressure (Emulsified blend fuels)

Figure 6 shows the CO emissions against engine speed for emulsified fuel without engine load. From this figure it can be seen that, the emulsified fuel and all the emulsified blend fuels, the CO emissions increase than the light fuel under all engine speeds. It is explained that the decreasing flame temperature because of water addition. On the other hand, the CO emissions of emulsified blend fuels are smaller than that of emulsified light fuel without low engine speed. It is the effects of oxygen in the vegetable oil.

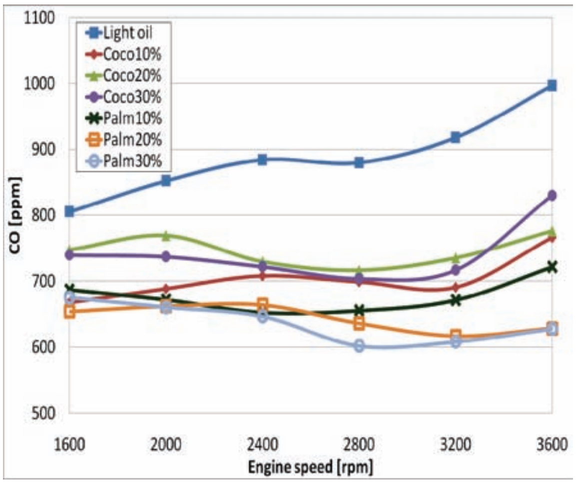

Fig. 4. CO emissions (Blend fuels)

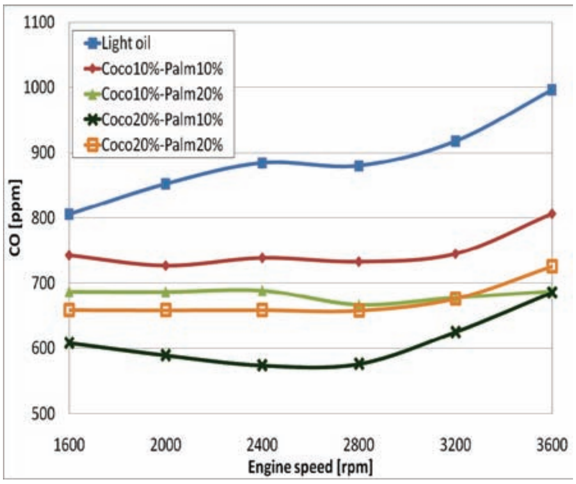

Fig. 5. CO emissions (Coconut+Palm blend fuels)

Figure 7 shows the CO emissions against engine speed for emulsified fuels of Coconut and Palm oil. For example, the triangle symbol is light oil 80 vol%, Coconut oil 10%, Palm oil 10% and 9.1mass% water. From this figure, the CO emissions for all the emulsified blend fuels of Coconut and Palm oil, are smaller than that of emulsified light fuels. Furthermore, under low engine speed conditions the CO emissions level is almost same or lower than that of the light oil under all engine speeds. It is explained that the micro-explosion's effects.

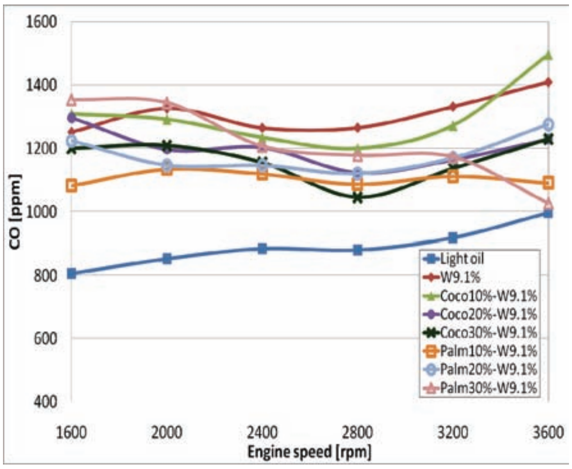

Fig. 6. CO emissions (Emulsified blend fuels)

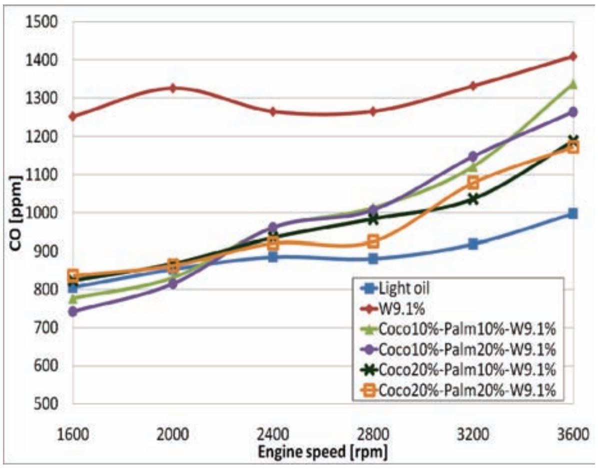

Fig. 7. CO emissions (Coconut+Palm emulsified blend fuels)

Figure 8 shows the NOx emissions against engine speed for blend fuels. As can be seen from this figure, NOx emissions for all the blend fuels are bigger than that of light oil. It is causes by the increasing the flame temperature by the oxygen addition in the vegetable oil.

Figure 9 shows the NOx emissions against engine speed for emulsified fuel without engine load. From this figure it can be seen that, for the emulsified light oil and all the emulsified blend fuels, the NOx emissions are lower or almost same level than that of light oil. It is explained that the thermal NOx decreases with decreasing the flame temperature by the water addition.

Figure 10 shows the NOx emissions against engine speed for emulsified fuels of both Coconut and Palm oil using. From this figure, the NOx emissions for all the emulsified blend fuels of Coconut and Palm oil are bigger than that of emulsified light fuels or light oil. From these results it can be seen that, for reducing the NOx emissions by using the emulsified fuels of Coconut and Palm oil, it is necessity to do the discuss the effects of the additional water.

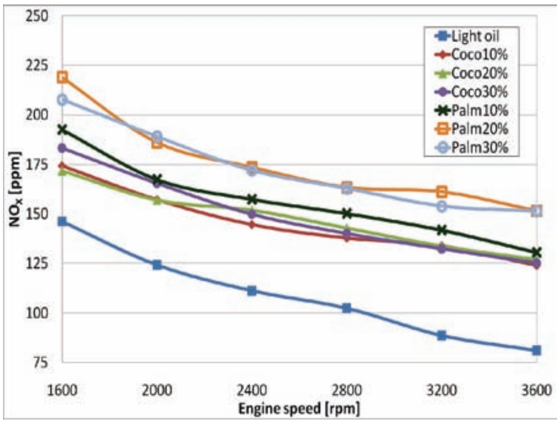

Fig. 8. NOx emissions (Blend fuels)

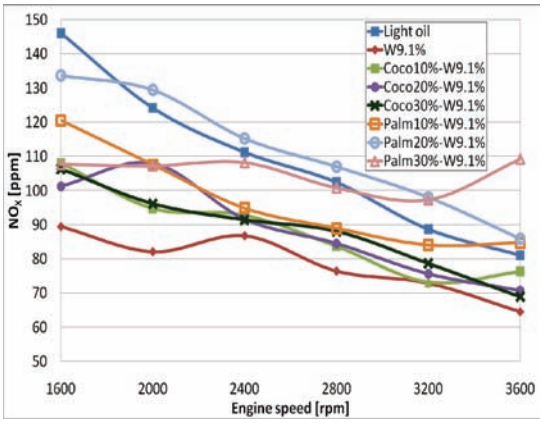

Fig. 9. NOx emissions (Emulsified blend fuels)

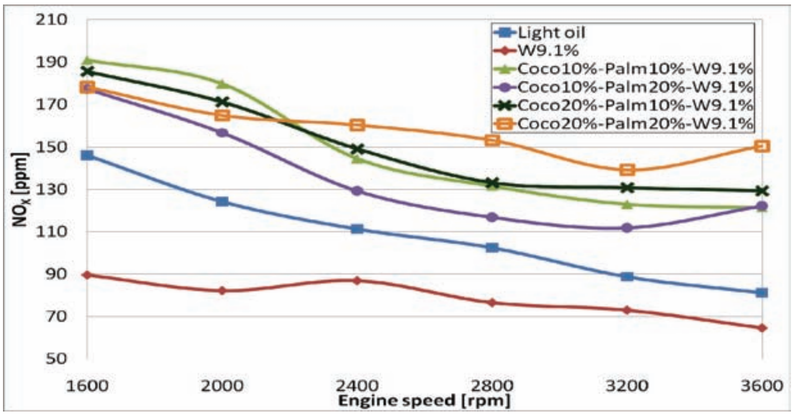

Fig. 10. NOx emissions (Coconut+Palm emulsified blend fuels)

Figure 11 shows the ratio of CO emissions against the engine speed. Where, the 1.0 ratio of CO emission means the same CO emission by using light oil at same engine speed. In other words, over the 1.0 means the increasing CO emissions than light oil at same engine speed. From this figure it can be seen that, the maximum reduction ratio of CO can possible by using the Coco20%-Palm10% of blend fuel and Coco10%-Palm10%-W9.1% of emulsified fuels.

Figure 12 shows the ratio of NOx emissions against the engine speed. Where, the 1.0 ratio of NOx emission means the same NOx emission by using light oil at same engine speed. From this figure, the maximum reduction ratio of NOx can possible by using the Coco10%-Palm10% in the blend fuel and Coco10%-W9.1% in the emulsified fuels.

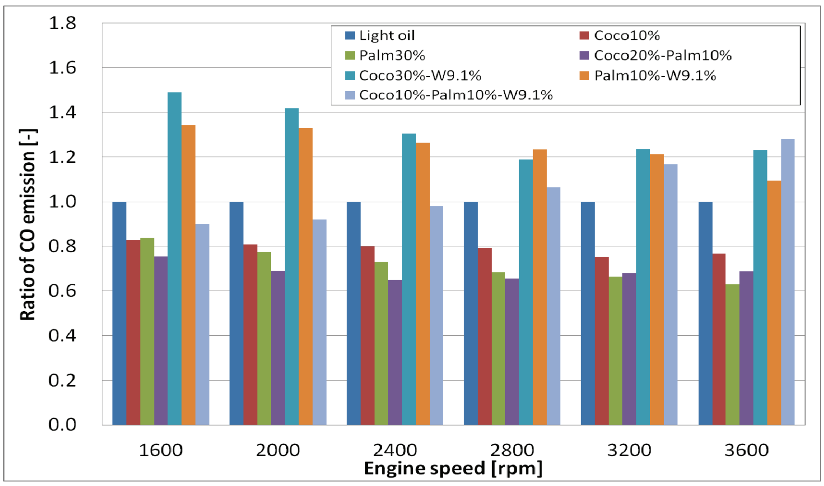

Fig. 11. CO emissions(All fuels)

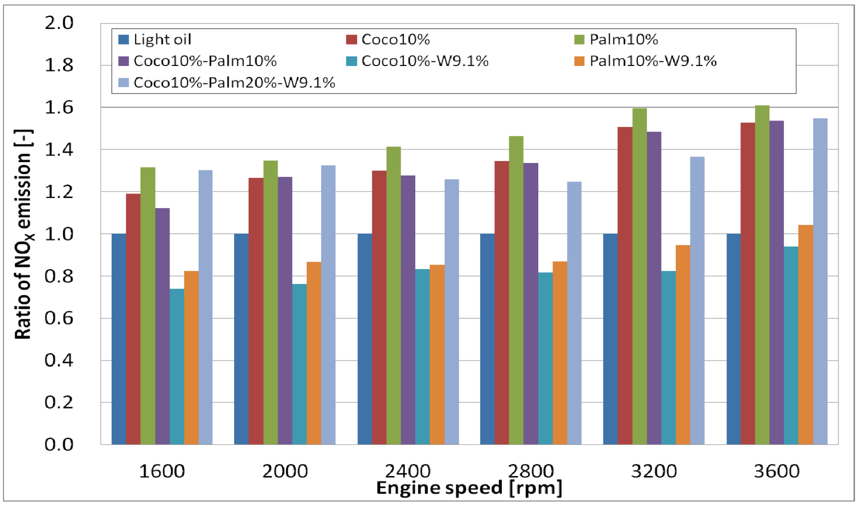

Fig. 12. NOx emissions(All fuels)

4. Conclusions

The main conclusions are as follows: 1) It is possible to control the combustion behaviour by using blend fuels and emulsified blend fuels for small diesel engine.2) The maximum burning pressure of emulsified blend fuels increases at low engine speed. 3) CO emission of blend fuels is smaller than that of light oil. 4) NO_X emission of emulsified coconut blend fuel and emulsified palm blend fuel is smaller than that of light oil. 5) CO emission of emulsified Coconut-Palm blend fuel is equal to that of light oil at low engine speed.

References

[1] Iijima, A., Shoji, H., *A study of HCCI combustion characteristics using Spectroscopic Techniques*, SAE paper 2007-01-1886, 2007.
[2] Tsutsumi, Y., Hoshina, K., Iijima, A., Shoji, H., *Analysis of the combustion characteristics of HCCI Engine operationg on DME and Methane*, SAE paper No. 2007-32-0041, 2007.
[3] Lim, O. T., et al, *The fuel unmixedness effect on DME HCCI combustion using rapid compression and expansion machine*, SAE paper No.2007-42-0042, 2007.
[4] Daisho, Y., et al, *Contolling combustion and exhaust emissions in a Direct-injection diesel engine dual-fueled with natural gas*, SAE paper, No.952436, 1995.
[5] Tomita et al, *Effects of EGR and early injection of diesel fuel on combustion characteristics and exhaust emissions in a methane dual fuel engine*, SAE paper, No.2002-01-2723, 2002.
[6] Hill, P. G., et al, *NO_x reduction from heavy-duty diesel engine with direct injection of natural gas and cooled exhaust gas recirculation*, International Journal of Engine Research, Vol. 5, No. 2, pp. 175-191, 2003.
[7] Tomita et al, *Combustion characteristics and performance of supercharged micro-pilot natural gas engine*, Proceedings of FISITA 2006 World Automotive Congress, Paper No. F2006, p. 230, pp. 1-10, 2006.