Influence of Jatropha FAME for the Diesel Combustion and Exhaust Emission Characteristics

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Abstract

The bio diesel fuel (BDF) is expected to solve the global warming. However, the BDF causes the food conflict issue because the BDF is mainly made from edible oil. According to this problem, Jatropha oil is in the spotlight as feasibility BDF. Jatropha oil is non-edible vegetable oil which can grow on the poor soil, and high yield coefficient. Therefore, this study was made on the use of Jatropha Fatty Acid Methyl Ester (FAME) as an alternative fuel for diesel engines.

In the experiment described in this paper, Jatropha FAME was blended with gas oil in order to improve the quantity supplied and characteristics of Jatropha FAME. The Jatropha FAME mixing ratios were varied from 10 to 30% in volume. The density and kinematic viscosity of Jatropha FAME and gas oil blended fuels were measured. It was found that the mixing of gas oil can improve the properties of Jatropha FAME. Finally, Jatropha FAME and gas oil blended fuels were burned in a conventional 320-cc diesel engine. Although the particle matter in the exhaust gas was confirmed to be reduced from the gas oil, yet nitrogen oxides were not increased. Furthermore, the brake specific fuel consumption was slightly lower than gas oil, total hydrocarbon and carbon dioxide (CO_2) emission were also reduced. And moreover, CO_2 emission can be reduced much more still, since BDF is considered with the Carbon Neutral.

Keywords*:* Bio diesel fuel, Jatropha oil, Fatty acid methyl ester, Gas oil blended

1. Introduction

Today, bio diesel fuels (BDF) are in the spotlight as feasibility alternative fuel because they are considered the fuel solving the global warming. Furthermore, they are anticipated as the sustainable renewable energy. Especially, Fatty Acid Methyl Ester (FAME) which is made by transesterification of vegetable oil and alcohol is expected, since it has good engine performance and low exhaust emissions [1-6]. However, the most of FAME are concerned the food conflict issue, due to they are made from edible oil. According to this context, Jatropha FAME has been more expected, lately.

Jatropha is deciduous shrub native to South America. It is known to grow up with the poor soil, and make high yield coefficient. Also, it is told that the expressed oil amount is three times as large as rapeseed. Moreover, Jatropha doesn't make the food conflict issue since it is non-edible plant. Jatropha contains the phorbol ester and therefore unfits to eat. This phorbol ester is the tumor promoter, but it is removed by neutralizing process of crude Jatropha oil. Consequently, Jatropha FAME can use as the safe fuel since phorbol ester is removed. It is declared with the research by the Japan national institute of advanced industrial science and technology (AIST) [7]. In addition, AIST has made Jatropha FAME pilot plant in Thailand with Thailand national science and technology development agency [8].

Jatropha FAME has above mentioned high practicability but quantity of production is little, and then Jatropha FAME cannot supply enough quantity against the demand. Therefore, Jatropha FAME is considered that it will be used by blending with the gas oil. In this paper, experimental study was made on Jatropha FAME and gas oil blended fuels. This paper describes the influence of Jatropha FAME and gas oil blended fuels for diesel combustion and exhaust emission characteristics.

2. Properties of Test Fuels

In this study, the properties of test fuels were investigated before the engine performance test in order to confirm the change of characteristics by Jatropha FAME blending. The test fuels were made by blending Jatropha FAME and gas oil. The Jatropha FAME mixing ratios were 10, 20 and 30% in volume, then each fuel were named JFAME10%, JFAME20% and JFAME30% respectively. Furthermore, gas oil (JIS #2) and neat Jatropha FAME were measured for the reference. This neat Jatropha FAME is shown as JFAME in the figures and tables.

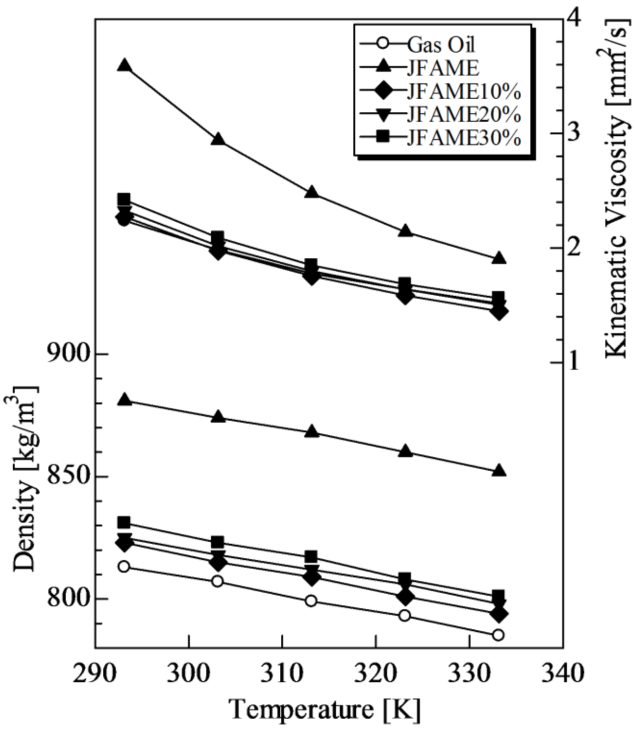

Fig.1 Density and Kinematic Viscosity

Table 1 Properties of JFAME and Gas Oil

	Gas Oil (JIS #2)	JFAME
Density [kg/m^3(@303K)]	807	874
Kinematic Viscosity [mm^2/s(@303K)]	1.98	2.94
Lower Calorific Value [kJ/kg]	42990	37080
HFRR [μm]	440	224
Pour Point [K]	265.5	275.5
Cloud Point [K]	-	275

Fig.1 gives the measured density and kinematic viscosity of test fuels. Density was measured by the float test, and viscosity was measured by using the viscometer (A&D; VM-

10A-L). Besides, Table 1 shows difference of the properties comparing JFAME and gas oil.

From this figure, it can be seen that the density and kinematic viscosity increases with the JFAME mixing ratio. And it is also found that JFAME and gas oil has difference but JFAME blended fuels are similar to gas oil. Density of JFAME is 880[kg/m^3(@293K)] but JFAME blended fuels are improved to around 825[kg/m^3(@293K)]. Particularly, kinematic viscosity is very close to gas oil. Kinematic viscosity of JFAME is 3.7[mm^2/s(@303K)] but JFAME blended fuels are improved to around 2.1[mm^2/s(@303K)]. Although this result is naturally since JFAME mixing ratios are small, close property is very important because it causes a similar fuel spray characteristics. This fuel spray characteristics, especially mean spray particle diameter changes the combustion characteristics such as ignition timing. Consequently, close ignition timing will get with the same diesel engine due to JFAME has similar Kinematic viscosity and cetane number [9] to gas oil. And furthermore, diesel engines are needed the enough lubrication with the fuels for the fuel pump and injector. This similar kinematic viscosity makes good lubrication inside of them, and it won't break them with respect to kinematic viscosity.

Table 1 presents properties comparing JFAME and gas oil. There are some differences, HFRR (High Frequency Reciprocating Rig) of JFAME is better than gas oil but lower calorific value and pour point are worse. HFRR is a factor of lubrication, therefore, it can be said that JFAME has good lubrication. Moreover, kinematic viscosity of JFAME is also well above mentioned, and then fuel pump and injector won't be broken. However, lower calorific value of JFAME is smaller than gas oil. Also, pour point of JFAME is higher than gas oil. It is concerned about worse fuel consumption, but it will be small difference since JFAME mixing ratios are small. But then, JFAME blended fuels must be regarded to use when the cold winter.

3. Engine Performance Test

3.1 Experimental Apparatus and Method

The engine performance test was carried out in order to declare the influence of Jatropha FAME and gas oil blended fuels for diesel combustion and exhaust emission characteristics. Fig.2 presents the engine performance test apparatus. The engine used in this study was air-cooled single cylinder direct injection diesel engine. The engine specifications are shown in Table 2. And then, the experiment was performed under the following conditions:

The engine was set five step loads by the dynamometer. These loads were selected up to the continuous horse power of the test engine. The pressure and temperature also the amount of intake air, cylinder pressure and crank angle, exhaust gas temperature, they were measured and recorded with the data logger. Exhaust gas was sampled directly from the exhaust pipe in order to measure the particle matter (PM) precisely by the opacity meter (HORIBA; MEXA-600SW). Also, exhaust emissions such as O_2, CO, CO_2, THC and NOx were precisely measured from directly sampled exhaust gas by using the exhaust gas analyzer (HORIBA; MEXA-9100D). In addition, engine performance such as brake specific fuel

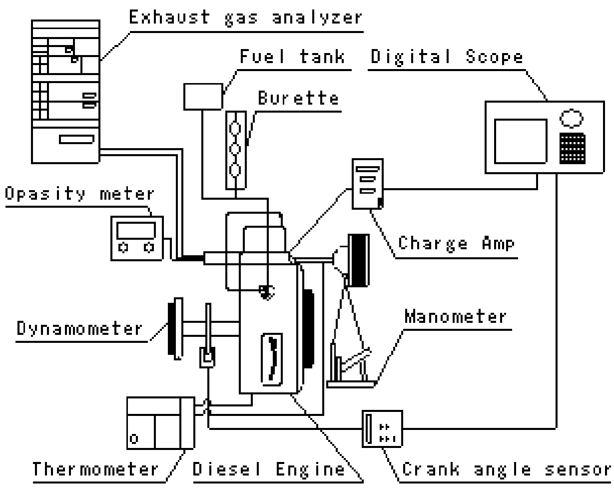

Fig.2 Experimental Apparatus

Table 2 Engine Specifications

Model	YANMAR L70V
Displacement Volume	320 [cc]
Compression Ratio	21.1
Continuous Power	4.3 [kW]@3600rpm
Maximum Power	4.8 [kW]@3600rpm
Fuel Pump	Plunger type
Fuel Injection Timing	BTDC16 [deg]
Injection Pressure	19.6 [MPa]

consumption (BSFC) was investigated. The all of measurements was precisely measured at each five loads while the steady state condition at 3000 rpm. Finally, combustion of each fuels were analyzed from recorded cylinder pressure and crank angle.

3.2 Results and Discussions

Fig.3 gives the engine performance test results of each fuel. The equivalence ratio is set on the horizontal axis because each fuel has different stoichiometric correct amount of air, exhaust emissions and BSFC are on the vertical axes in this figure. In addition, the cylinder pressure and heat release rate at the highest load are shown in Fig.4.

From Fig.3, it can be seen that exhaust emissions trend of JFAME blended fuels are different from gas oil, and they are similar to JFAME. Oxygen in the exhaust gas of JFAME and JFAME blended fuels are higher than gas oil. Jatropha FAME has oxygen inside the molecules, due to its components are oleic acid and linoleic acid mainly. Accordingly, this oxygen from fuel increases oxygen in the exhaust gas. This can be considered that the oxygenated fuel supports the combustion but surplus oxygen increases the exhaust gas. Because carbon monoxide (CO) and total hydrocarbon (THC) also PM of JFAME and JFAME blended fuels are not increased, rather they are reduced. Therefore, cause of oxygen increase is not from incomplete combustion, there is the supporting combustion action from oxygenated fuel but surplus oxygen increases the exhaust gas. Furthermore, carbon dioxide (CO_2) of JFAME blended fuels are lower than gas oil. Equally, this can be considered that cause of CO_2 reduction is not from incomplete combustion, since CO and THC also PM are significantly reduced.

From Fig.4, it can be declared that JFAME and JFAME blended fuels have smaller diffusion combustion period and after combustion period than gas oil. The short ignition delay leads short premixed combustion period. And then, short premixed combustion period leads short diffusion combustion period and after combustion period. This diffusion combustion period and after combustion period make PM in a word, therefore small diffusion combustion period and after combustion period lead to PM reduction; this is to say that short ignition delay makes PM reduction. In addition, since Jatropha FAME is oxygenated fuel that contains oxygen molecules, JFAME is readily oxidized with the available oxygen in the flame zone and then PM is reduced, above mentioned. Consequently, PM is drastically reduced.

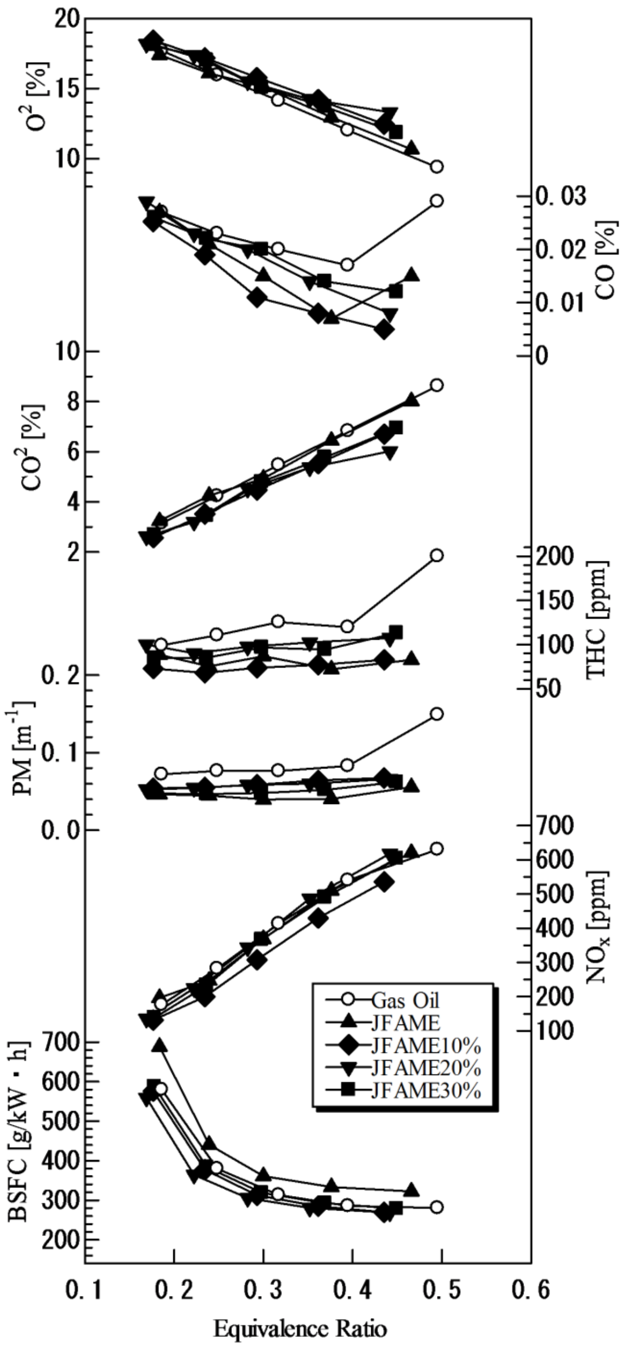

Fig.3 Engine Performance Test Results

PM of JFAME and JFAME blended fuels are confirmed to be reduced, but nitrogen oxides (NOx) are not increased. Diesel combustion generally makes trade off relationship between NOx and PM [10]. Accordingly, PM reduction makes NOx increase normally. However, NOx is not increased but PM is reduced. This means, NOx is reduced by the amount of it should be increased. From Fig.4, it can be seen that JFAME and JFAME blended fuels get shorter ignition delay and higher premixed combustion. The shorter ignition delay causes generally lower premixed combustion, but it is higher. In addition, higher premixed combustion causes high NOx,

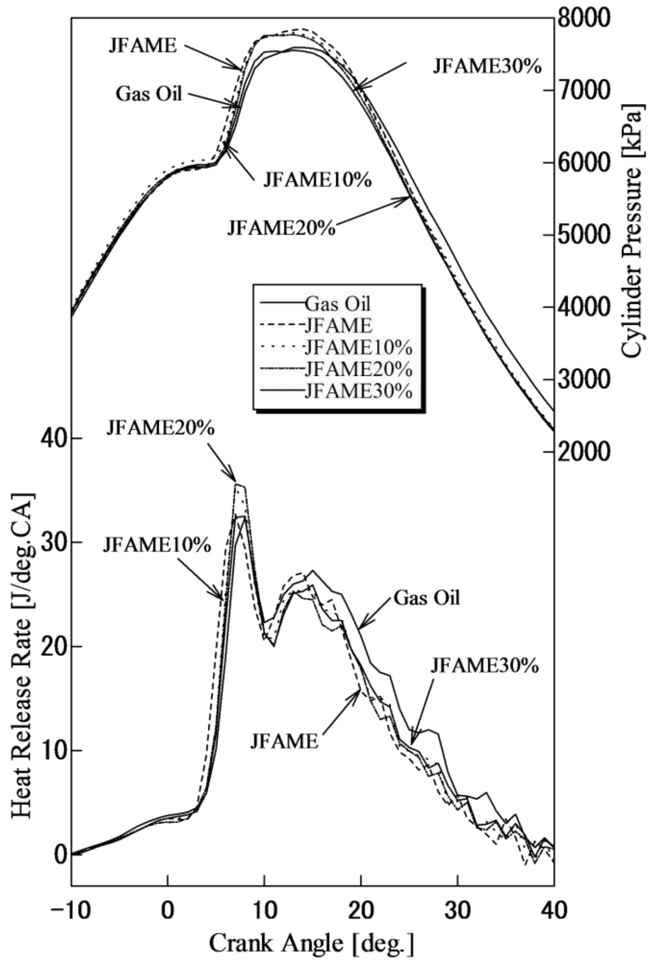

Fig.4 cylinder Pressure and Heat Release Rate at the highest load but it is not high. Therefore, it can be considered that the micro explosion effect is taken place while the ignition delay. JFAME in the fuel spray begins to boil faster than gas oil due to the boiling point of JFAME is lower than that of gas oil. Accordingly, rich area particularly the center of combustion chamber is dispersed into the whole combustion chamber. This rich area makes high temperature, and then thermal NO is increases, moreover rich area also makes prompt NO, therefore NOx is increased with the rich area. Consequently, this dispersed rich area causes NOx reduction; in brief the micro explosion effect makes NOx reduction.

The result mentioned above, exhaust emissions of JFAME and JFAME blended fuels have similar trend. However, there is significantly different trend on BSFC between JFAME and JFAME blended fuels. JFAME blended fuels are slightly lower than gas oil, though JFAME is higher than gas oil. This can be seen that difference of lower calorific value causes different BSFC. Jatropha FAME has small lower calorific value. Accordingly, BSFC of JFAME is worse but JFAME blended fuels are not worse because mixing ratios are little. Furthermore, JFAME blended fuels have short ignition delay and then combustion starts early to top dead center. For that reason, JFAME blended fuels can get lower BSFC. This result of BSFC can be vouched by the result of CO_2 emission. CO_2 reduction is not from incomplete combustion above mentioned, it is result of scarce fuel. Consequently, BSFC of JFAME blended fuels are reduced. And furthermore, CO_2 emission of JFAME blended fuels can be reduced much more still, since BDF is considered with the Carbon Neutral. Therefore, the blending ratio can be seen as the CO_2 emission reduction ratio.

4. Conclusions

In this paper, the experimental study was made on the use of Jatropha FAME and gas oil blended fuels as an alternative fuel for diesel engines. The fuel properties were measured before the engine performance test. And then, Jatropha FAME and gas oil blended fuels were burned in a conventional diesel engine in order to investigate the influence of them for diesel combustion and exhaust emission characteristics. The main conclusions can be summarized as follows:

1) JFAME and gas oil has different properties but JFAME blended fuels are similar to gas oil. Particularly, kinematic viscosity is very close to gas oil, and then fuel pump won't be broken with respect to kinematic viscosity.
2) HFRR of JFAME is better than gas oil but lower calorific value and pour point are worse. The fuel consumption will be worse, but it will be small difference since JFAME mixing ratios are small. However, JFAME blended fuels must be regarded to use when the cold winter.
3) Oxygen in the exhaust gas of JFAME and JFAME blended fuels are higher than gas oil, and CO_2 is reduced. This cause is not incomplete combustion because CO and THC also PM of JFAME and JFAME blended fuels are not increased, rather they are reduced.
4) PM of JFAME and JFAME blended fuels are drastically reduced by the supporting combustion action from oxygenated fuel. Moreover, small diffusion combustion makes PM reduction.

5) Although PM is reduced, yet NOx of JFAME and JFAME blended fuels are not increased, therefore they must be reduced. It seems that cause of NOx reduction is the micro explosion effect.
6) BSFC of JFAME blended fuels are slightly lower than gas oil, though JFAME is higher than gas oil. It seems that difference of lower calorific value and short ignition delay makes different BSFC.
7) CO_2 of JFAME blended fuels are reduced by lower BSFC due to short ignition delay. And furthermore, CO_2 emission can be reduced much more still, since BDF is considered with the Carbon Neutral.

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