Effect of Organic Solution based Additive on Exhaust Emissions of an Indirect Injection Diesel Engine

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Abstract
Exhaust emission from engine combustion is concerned increasingly to environmental effect. Fuel additives mixed for reduction of the exhaust are more interested based on no modification of the engine. In this study, exhaust emission and performance of an indirect injection diesel engine were investigated under the various fuel test conditions with mixing additive based organic solution. The various fractions of palm oil biodiesel (POB) in the rest of diesel fuel from 2% to 100% denoted as B2 up to B100, respectively were considered. The improvement of POB fuel properties with using organic additive based oxidative desulfurization in the blended fuels in order to allow in the set regulations of Thai Department of Energy Business (DOEB). The modified fuels by blending the 0.1g additive in 2.5 liters diesel fuel tested were prepared and measured the physical properties such as viscosity, cetane number, flash point, heating value, and carbon residue of the modified fuels under ASTM standard test methods. The effect of the additive in POB blended fuel on CO, CO_2, and NO_x was investigated in this study. Comparing with the same fraction of POB blend without additive, the significant improvement of POB properties of all POB fuels adding the organic additive was obtained. Their properties for high POB fraction of B40 with additive are still allowed under the set regulations of DOEB. In addition, the experimental results showed the effective decrease of the exhaust emissions from using the organic additive in comparison with POB fuels in the same fraction.

Keywords: organic solution additive, diesel engine, palm biodiesel, fuel property, exhaust emissions

Introduction

Diesel engine generally emits exhaust in particular NOx more than emission from gasoline engine, which causes higher pollution. Increasing ambient air pollution force the researches to concern clean alternative fuels for diesel engines. Palm oil biodiesel (POB) is an alternative fuel due to its various advantages, such as abundant biomass resources, biodegradable and environmental friendliness over fossil fuel [1]. Moreover, biodiesel predominantly produced from biomass is becoming cost competitive with fossil fuels due to the widespread availability of biomass resource [2]. However, some POB fuel properties with high exhaust emissions are not allowed in the set regulation of energy business. Addition of organic additive is an alternative for improving POB fuel properties and reducing the exhaust emissions [3,4].

In the present, there are several kinds of bio-solution based additive to be synthesized for appropriate bio-oil blends, for example, ethers based (ETBE: C6H14O and TAEE: C7H16O etc.) [5], ethanol based (C¬2H5OH) [6] or glycerol based (C3H8O3) [3] in palm biodiesel. The influence of organic solution based oxidative desulfurization blending in palm oil biodiesel has been studied insufficiently. Thus, the aim of this work is to verify the comparative engine performance and gas emissions of an indirect injection (IDI) pickup automobile which was fueled by POB with additive at the different POB fractions from B2 to B100.

In this study, the commercial organic additive based oxidative desulfurization was used oxidizing the sulfur compounds in the diesel fuel to sulfones. Due to their high polarity, the sulfones thus formed are readily removed from the fuels by polar extraction. The commercial organic additive is thus highly effective in removing sulfur compounds from the fuels. The influence of the additive in POB fuel under varying fuel fractions was examined. In order to determine the available POB fraction and achieve the reduction of the exhaust emissions, an IDI pick-up diesel engine was tested on a FPS 2700 chassis dynamometer. All tests were performed without any modifying engine. NOx, CO and CO2 emissions from the engine were measured by Testo 350 gas analyzer.

Experimental Procedures

The various POB fuel fractions in the rest of diesel fuel from 2% to 100% denoted as B2 up to B100, respectively were tested. A small amounts of the additive of 0.1g in 2.5 liters POB fuel were used for dosing in the various POB blends. The physical characteristics of the tested fuels were measured in this study including kinematic viscosity, flash point, cetane index, heating values, and carbon residue. The influences of the additive on the physical properties of the various fuels tested were investigated. The various POB fuels blending the organic additive were produced by means of an ultrasonic shaker for 15 minutes in order to obtain the uniform suspension.

The used vehicle in this experiment was a standard pickup car with a manual gear box. The schematic of the experiment setup is shown in Figure 1. The tested engine specifications were listed in Table 1. The FPS 2700 chassis dynamometer under the simulation of road load conditions with eddy current brake was conducted in this experiment. Measuring accuracy of the chassis dynamometer is of ± 2%. The performance correction was use by following a standard of SAE J. 1349. Each engine test was repeated 3 times to ensure the average data calculation for the analysis. Owing to the different fuels tested, each engine test was on a standard of the operating conditions.

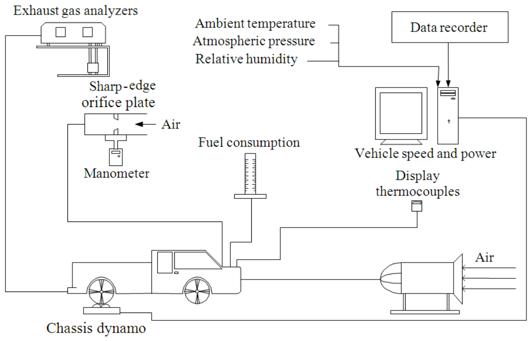

Figure1: The schematic of experiment setup

Table 1: Test engine specification

Engine	TD27(New)
Displacement	2663 cc
Bore x Stroke	96.0 × 92.0 mm
Cooling system	Water cool
Intake Method	Natural aspiration
Maximum Power	83.8 bhp@4000rpm
Maximum Torque	166Nm-@2200rpm

Exhaust emissions and gas temperature, according to SAE J816B specifications were measured by a Testo 350 gas analyzer. Measurement resolutions for NO_x, CO, and CO_2 are 0.1%, 1.0%, and 0.01% ppm, respectively. Meanwhile, measurement capacity for NO_x, CO, and CO_2 are in the range of 0-500 ppm, 0-10,000 ppm, and 0-50% vol., respectively. Exhaust emission values were measured directly by sampling the gas emission data, which was detected at the exhaust pipe with the analyzer probe as shown in Figure 1. The test cycle was repeated three times. The software provides extraordinary data management capability and the ability to import/export data.

Results and discussion

The obtained data of basic properties of the blended fuels is detailed in Table 2. It is noted that when the additive was blended in the POB fuels with all fraction conditions, the quality of all basic properties was improved for all blended POB conditions. Moreover, the property values of the blended POB fuel were allowed under the ASTM standard except B50 and B100 blended fuel below the standard. As can be seen, all viscosity and carbon residue values of the blended POB fuels decreased comparing with the same POB fuel fraction. Low viscosity and carbon residue can result in the fine aerosol distribution of the blended POB fuel and less soot in the pumping system. As illustrated, all cetane numbers, heating values and flash point of the blended POB fuel increased, which obtain the complete combustion and safer handling.

As illustrated in Figure 2, from the tested engine using the blended POB the exhaust NOx level effectively decreases throughout the engine speed test for all fraction conditions, especially the blended POB fractions above B20+Add, which obtain NOx emission increasingly reduced. This is mostly due to the organic additive based oxidative desulfurization is highly effective in removing sulfur compounds from the fuels. Under the set regulation standard, the appropriate POB fuel fraction at B30+Add resulted in the average minimal NOx emission of 12.35 ppm.
Figure 3 shows CO level emiting from the engine to be fueled by the different blended POB fuels comparing with B2 as reference fuel. It was found that high POB fraction above B10+Add obtained the effective reduction of CO emission. B30+Add fuel had an impact on the minimal CO level of 62.50 ppm average value.
As can be seen in Figure 4, the average CO2 emission was minimize of 0.57% vol from the engine using B30+Add. However, comparing with B2 the average CO2 level increased for using B2+Add and B10+Add, which correspond to the result of CO2 emission. It may be due to that the organic additive can effectively catalyze to high fraction of POB.

Table 2 : The basic properties of the test fuels

Fuel	Kinematic Viscosity (cSt)	Flash point (^{o}C)	Cetane index	Heating value (MJ/kg)	Carbon Residue (% wt.)
ASTM Standard	ASTM D445 1.8-4.1	ASTM D93 > 52	ASTM D976 > 50	ASTM D240 > 42.5	ASTM D524 <0.05
B2	3.92	66	56.87	44.39	0.01
B10	4.02	65	55.99	43.79	0.04
B20	4.11	70	56.92	43.64	0.07
B30	4.16	85	56.30	37.25	0.31
B40	4.38	83	56.53	37.40	0.31
B50	4.52	90	55.22	38.22	0.69
B100	5.46	135	49.04	37.62	0.89
B2+Add	3.53	64	61.35	45.89	0.05
B10+Add	3.62	71	60.97	45.41	0.05
B20+Add	3.72	72	59.76	44.62	0.04
B30+ Add	3.91	74	59.67	43.79	0.03
B40+ Add	4.05	81	58.78	43.44	0.05
B50+ Add	4.23	82	59.16	42.89	0.07
B100+Add	5.34	153	52.40	40.94	0.08

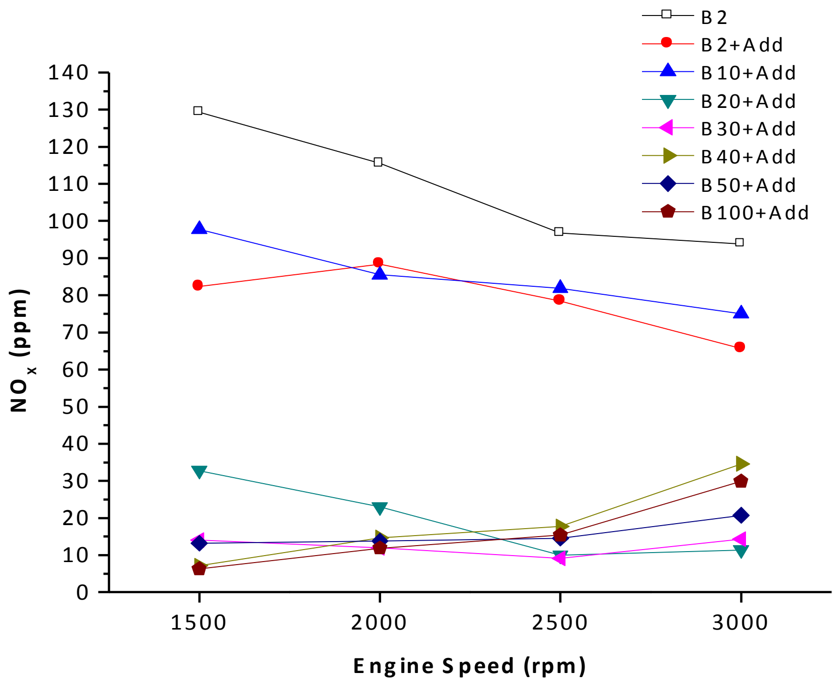

Figure 2 : NO_x emissions from the engine to be fueled by the blened POB fuels in the different conditions.

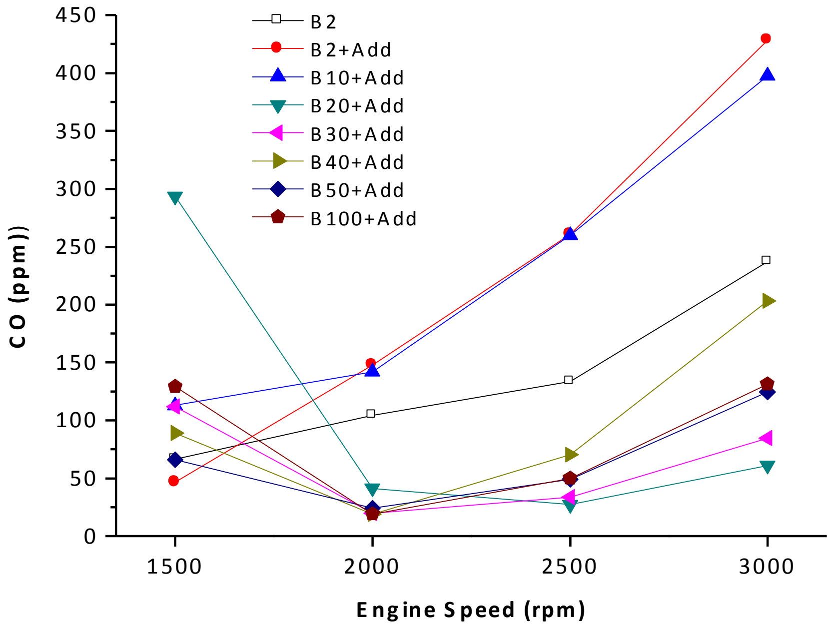

Figure 3: CO emissions from the engine to be fueled by the blened POB fuels in the different conditions.

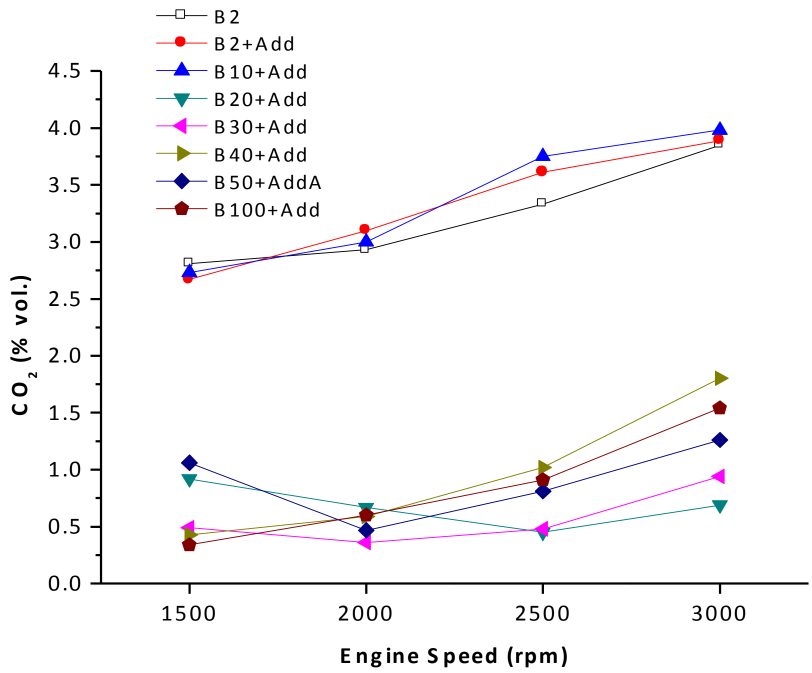

Figure 4: CO_2 emissions from the engine to be fueled by the blened POB fuels in the different conditions.

Brake power and wheel power were measured at the engine speed from 1500 rpm to 4000 rpm during engine operation to be fueled the blended POB fuels as shown in Figure 5. It was found that the brake power and wheel power for using the different blended POB fuels merely droped comparing with using B2. As be allowed under the standard, the brake power merely reduced by 0.97% and 2.80% for B30+Add and B40+Add, respectively, which compared with B2. Therefore, organic based oxidative desulfurization is an alternative additive for improving POB fuel properties and reducing exhaust emission.

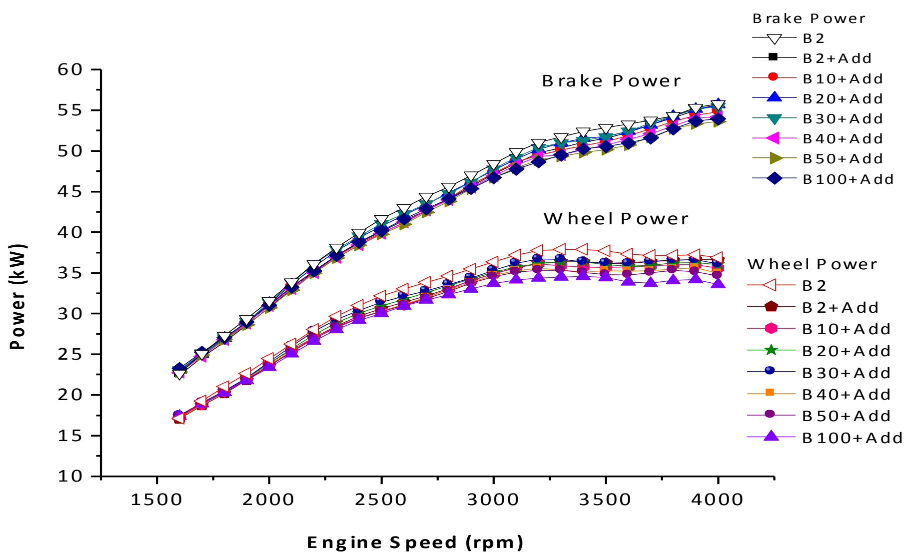

Figure 5: Variation of the brake and wheel powers for standard B2 and blended POB fuels

Conclusions

Adding organic solution based oxidative desulfurization as a catalyst in the POB fuels is an effective method to reduce the exhaust emission from IDI engine. The different blended POB fuel fractions were determined the physical properties under ASTM standard methods. It was indicated that organic additive blended in POB fuels is very effective on the reduction of the NO_x, CO, and CO_2 emissions because the organic additive based oxidative desulfurization is highly effective in removing sulphur compounds from the fuels. Under allowance of the set regulation standard, the appropriate POB fraction was B30+Add and B40+Add, which contributed to the maximum reduction of the exhaust emission. Meanwhile, the engine power measured from the tested engine fuelled by the blended POB fuels had the merely decrease, which compared with B2

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