Effect of Nano-TiO_2 Additives Blended in Palm Biodiesel on Compression Ignition Engine Performance

Karoon Fangsuwannarak, Thipwan Fangsuwannarak, and Yongsathon Khotbut

***Abstract*—The property improvement of palm oil biodiesel (POB) was investigated by mixing a nano-TiO_2 additive in order to achieve in the decrease of exhaust emissions of a diesel engine. The different POB fuel fractions were used including B10, B20, B30, B40, B50, and B100 which are compared with commercial diesel B2 as a fuel standard. The results suggested that the small amount of 0.1% wt nano-TiO_2 additive provided the property improvement such as a decrease in kinematic viscosity and an increase in flash point, cetane index, and heating values. However, there are B2+0.1%TiO_2 and B10+0.1%TiO_2 providing their properties to be accepted in ASTM standard. The experimental results suggested that engine power and torque increased during the range of low engine speed (<2500 rpm) and became decreased during the higher range of engine speed (>3000 rpm). Carbon oxide (CO), carbon dioxide (CO_2), and nitric oxide (NO_x) emissions were measured directly at the tailpipe in order to observe the effect of POB fuel used on the gas emissions. It was found that nano-TiO_2 additive significantly contributed the reduction of CO_2 and NO_x emissions.**

***Index Terms*—Palm biodiesel, nano-TiO_2 additives, compression ignition, engine performance.**

I. Introduction

In the present, environmental concerns increase due to decreasing fossil fuel and increasing ambient air pollution from gasoline engine in particular high-speed diesel engine. Biodiesel fuels can clearly provide positive environmental benefits because of one involvement of high oxygen content in biodiesel fuel to be biodegradable through antioxidant mechanism [1]. Biodiesel as an alternative fuel available for diesel engine is predominantly produced from virgin vegetable oil or animal fats through the chemical reactions to involve transesterification and esterification processes. In Thailand, palm oil biodiesel (POB) fuel is playing an important role on the bioenergy development due to having a massive energy plantation. The renewable and alternative energy development plan has set up the production target at 4.5 million liters/day in 15-year plan. Nevertheless, the massive palm feedstock has been concerned and managed for reducing adverse impact on the environment [2]. While biodiesel is becoming cost competitive with fossil fuels owing to the widespread availability of biomass resource [3], [4]. Meanwhile, previous studies presented that a decrease in engine power relates to an increase in volume fraction of palm oil biodiesel (POB) [5], [6]. These causes lead to more studies to upgrade the fuel quality and engine performance as well as reduction of exhaust emissions without modifying diesel engine. In addition, there are many studies to focus on the improvement of POB properties by blending an effective additive in the optimal diesel fuel fraction [7]-[9]. While tailpipe emission from using POB fuel depend on the POB blend in diesel fuel used, the kind of additive used, and the type of engine. Nano-titanium dioxide (TiO_2) additive is a kind of metal oxide materials to be claimed that it can improve solid propellent burn rates. It would result from the high surface-to-volume of the nanoparticles to provide a better catalyst than traditional additives [10]. However, the effect of nano-TiO_2 additive on exhaust emissions have not studied extensively in order to improve air quality. The demonstrations in this study were performed without any modifying engine.

This work studied the effect of nano-TiO_2 blend into palm biodiesel on the properties comparing with ASTM standard. Moreover, engine performance test was demonstrated on a FPS 2700 chassis dynamometer. Exhaust emissions such as NO_x, CO and CO_2 from operation of an indirect injection pick-up diesel engine were studied under SAE J816B standard. The exhaust emission results were presented.

II. Experimental Procedures

A. Preparation of Palm Oil Biodiesel

In this study, the POB fuel mixtures of purified palm oil and premium diesel oil were measured to verify their properties. The various fractions of palm fuel in diesel were investigated including 2%, 10%, 20%, 30%, 40%, 50%, and 100% palm biodiesel with the rest of diesel fuel fraction denoted as B2, B10, B20, B30, B40, B50, and B100, respectively. In this experiment, small amount of nano-TiO_2 of 0.1% by weight was used as a catalyst. The properties of the tested fuel were measured including kinematic viscosity, flash point, cetane index, and heating values. The experimental results were compared with the properties of B2 to be a commercial POB diesel. The composed POB fuel from the mixture of purified palm oil, premium diesel, and 0.1%wt nano TiO_2 additive was blended by means of an ultrasonic shaker for 15 minutes in order to provide the uniform suspension.

B. Engine Performance Testing

The used vehicle in this experiment was a standard pickup car with a manual gear box. The schematic of the experiment setup is depicted in Fig. 1.

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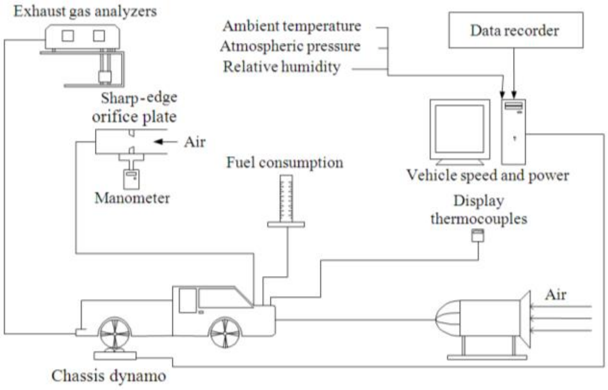

Fig. 1. Schematic of experiment set up.

The tested engine specifications were listed in Table I. 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. The accuracy of wheel power of ± 3% was obtained. Fuel consumption system was set upped and coupled with the fuel pump in order to examine the amount of fuel consumption. 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.

TABLE I: SPECIFICATIONS OF THE TESTED ENGINE

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

C. Exhaust Emission Testing

According to SAE J816B specifications, exhaust emissions were measured by a Testo 350 gas analyzer. Measurement capacity for NO_x, CO, and CO_2 is in the range of 0-500 ppm, 0-10,000 ppm, and 0-50% vol., respectively. Exhaust emissions were measured directly at tailpipe by the analyzer probe. The test cycle was repeated three times.

III. RESULTS AND DISCUSSION

A. Comparative Properties of POB Fuels

The aim of using additive is to improve the quality of POB fuel blend in order to possibly further use the less diesel. The properties of the different POB fuels showed the measured results to involve their identity quality in Table II. The results suggested that small amount of nano-TiO_2 of 0.1%wt provides the significant improvement of the fuel quality to compare with different POB fuel blends with no additive. It is noted that nano-TiO_2 contributed to increase flash point, cetane index and heating value, in addition, to reduce kinematic viscosity of POB fuels. Therefore, the data obtained from testing POB fuels belongs to the ASTM standards for B2, B10, B30, and B40 with dosing nano-TiO_2.

TABLE II: COMPARATIVE PROPERTIES OF POB FUELS

Fuel	Kinematic Viscosity (cSt)	Flash point (°C)	Cetane index	Heating value (MJ/kg)
ASTM Standard	ASTM D445 1.8-4.1	ASTM D93 > 52	ASTM D976 >50	ASTM D240 >42.5
B2	3.92	66	56.87	44.39
B10	4.02	65	55.99	43.79
B20	4.11	70	56.92	43.64
B30	4.16	85	56.30	37.25
B40	4.38	83	56.53	37.40
B50	4.52	90	55.22	38.22
B100	5.46	135	49.04	37.62
B2+0.1%	3.64	76	57.05	42.74
B10+0.1%	3.80	74	57.36	41.69
B20+0.1%	4.05	70	57.07	40.48
B30+0.1%	4.16	84	56.58	44.32
B40+0.1%	4.34	80	55.91	43.12
B50+0.1%	4.38	82	54.90	40.41
B100+0.1%	5.34	150	49.55	39.80

B. Comparative Engine Performance

Fig. 2 shows the engine power from using different POB fuel blend to be dosed by nano-TiO_2 additive. All tests provided the maximum power at engine speed of 4000 rpm. It was found that the increased trend of the power for POB fuel mixing the additive is similar to B2. Almost all the POB fuels mixing the additive provided the small increase of power at the range of low engine speed (< 2500 rpm) comparing with B2 but the measured power became lower at the range of higher engine speed (>3000 rpm.) It is mostly possible due to that the properties of heating value and cetane index of POB fuel were improved from the blend of nano-TiO_2 additive.

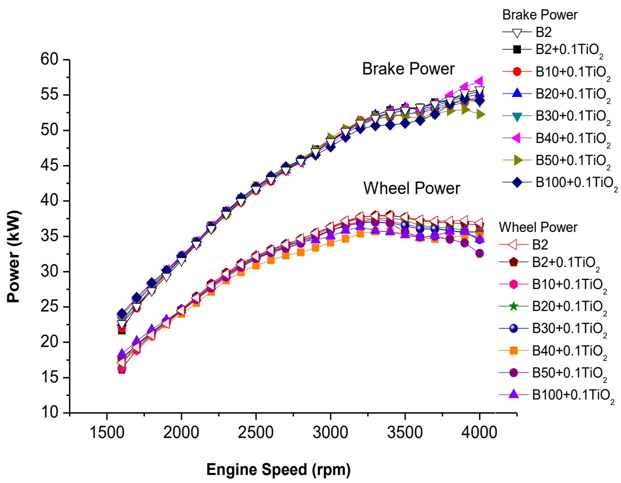

Fig. 2. Power of the engine to consume the different POB fuel blends comparing with B2.

Fig. 3 presents the toque of engine operation with different POB fuel used. The maximum torque is 166 Nm at engine speed of 2200 rpm. Similarly, torque curve for POB fuels does by additive showed the similarity trend comparing with B2 used. It was seen that engine torque increased at the range of low engine speed (< 2500 rpm.) comparing with B2. On the other hand, engine torque values decrease when the engine operates at the range of higher engine speed (> 3000 rpm).

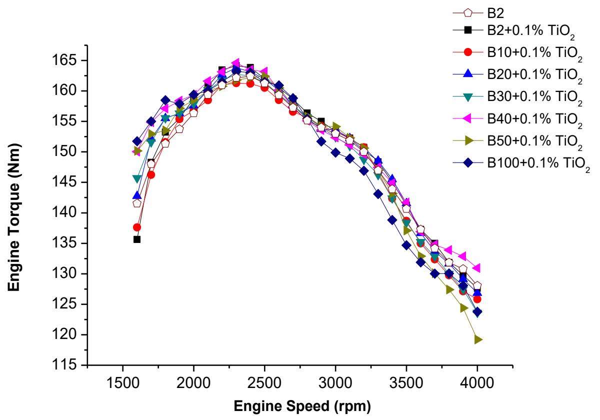

Fig. 3. Toque of the engine to consume the different POB fuel blends comparing with B2.

C. Exhaust Gas Emissions

Carbon oxide (CO), carbon dioxide (CO_2), and nitric oxide (NO_x) emissions were directly measured during the engine was operating at 1500, 2000, 2500, and 3000 rpm in order to observe the variation of exhaust gas emissions. The comparison of CO results of POB fuel blend with additive used and B2 used was illustrated in Fig. 4. The results showed that the CO emission quantity significantly reduced at higher engine speed (2500-3000 rpm.) in particular B10+0.1%, B20+0.1%, and B30+0.1%TiO_2 The main cause would be from the increase of oxygen composition in vegetable oil to result in more completely internal combustion in the engine and then lead to obviously reduction of CO emission [4], [9]. At low engine speed of 1500 rpm., all POB fuel tests provided more CO emission results than used B2 except using B2+0.1%TiO_2 that obviously reduced CO emission. Thus, 0.1% nano-TiO_2 in the optimal POB fuel blend is a very effective use of CO reduction for a high speed engine due to that nano-TiO_2 acts as an oxidation catalyst.

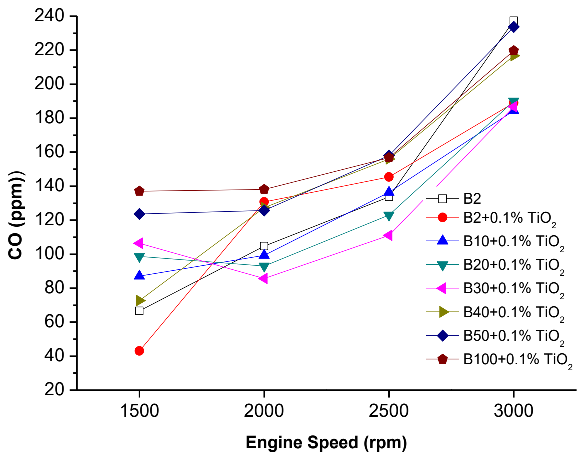

Fig. 4. Variation of CO emission for different POB fuels with mixing 0.1%wt nano-TiO2 comparing with B2 standard fuel.

Fig. 5 shows the effective decrease of CO_2 emission during engine operation at 1500 – 3000 rpm. The results suggested that the maximum CO_2 reduction at 1500 rpm is by 23%, 33%, and 43% for B10+0.1%, B20+0.1%, and B30+0.1%TiO_2, respectively, that compared with B2. Meanwhile, at 3000 rpm, the CO_2 emission results for B10+0.1%, B20+0.1%, and B30+0.1%TiO_2 comparing with B2 provided the decreased values by 11%, 14%, and 21%, respectively.

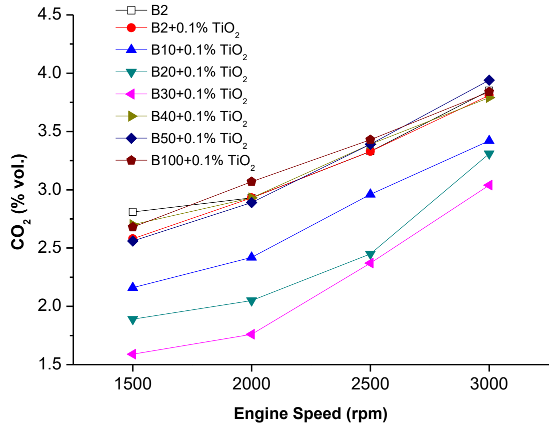

Fig 5. Variation of CO_2 emission for different POB fuels with 0.1%wt nao-TiO_2 additive comparing with B2 standard fuel.

NO_x emission can affect directly the corrosive in engine system. The variation of NO_x emission under engine operation using the POB fuels was measured at the different speeds and provided the results as depicted the in Fig. 6 It was found that almost all the POB fuels with mixing nano-TiO_2 additive provided the effective reduction of NO_x emission throughout the speed range, whereas B2+01%TiO_2 fuel contribute the increase of NO_x in the range of engine speed at 2500 – 3000 rpm. It may occur the feature of the inappropriate mixture of air and the fuel during combustion at higher engine speed. The maximum NO_x reduction was obtained from using B30+0.1%TiO_2 by 61%, 49%, 29%, and 17% at 1500, 2000, 2500, and 3000 rpm, respectively, that compared with B2.

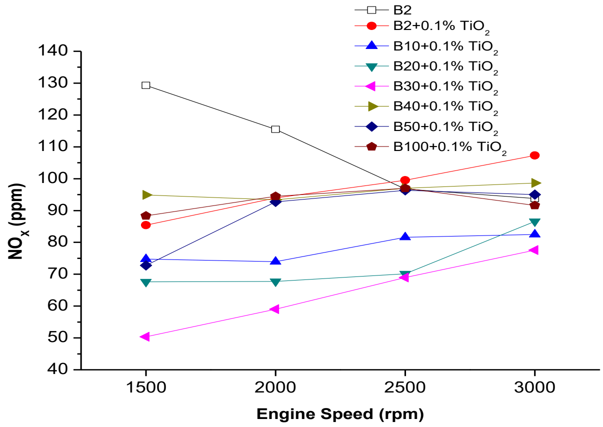

Fig 6. Variation of NOx emission for different POB fuels with 0.1%wt nao-TiO_2 additive comparing with B2 standard fuel.

IV. Conclusions

The quality improvements of palm oil biodiesel fuel were investigated in order to compensate the diesel fuel consumed increasingly. There is not only the use of an alternative POB fuel for above reason but the POB fuel also contributes the reduction of gas emissions. In this work, we studied the effect of nano-TiO_2 additive mixed in the different POB fuel fractions on the performance of an indirect injection diesel engine and exhaust emissions. The results suggested that POB fuel properties were improved by nano-TiO_2 additive as a catalyst. The improved properties of the POB fuels related to the improvement of engine power and torque that provided the similarity of the results from using B2. Meanwhile, CO_2 and NO_x emissions for B30+0.1%TiO_2 extremely reduced by 43% and 61%, respectively at the engine speed of 1500 rpm that compared with the results for B2. While, the engine operated at 3000 rpm, then B30+0.1%TiO_2 provided CO_2 and NO_x emissions reduced by 21% and 17%, respectively.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Dr. Karoon Fangsuwannarak conducted the research; Mr. Khotbut, Dr. Karoon Fangsuwannarak and Dr. Thipwan Fangsuwannarak analyzed the data; Dr. Karoon Fangsuwannarak and Dr. Thipwan Fangsuwannarak wrote the paper; all authors had approved the final version.

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