The Ability to Use 50% Biodiesel and Supercharging Syngas in Dual Fuel Mode for a Turbocharging Diesel-engine Generator

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***Abstract*—The current renewable fuels, such as diesel oil mixed to 50% biodiesel (B50) and syngas, are being interested in applying with diesel engines in some parts of Asia. The main objective of this research is to investigate the use of B50 and this oil combined to supercharging syngas from gas flow rate 76 to 125 lpm in dual fuel mode with a turbocharging diesel-engine generator. Results of engine testing indicate that using B50 has lower engine performance and emissions than diesel oil. On the other hand, compressing syngas up to 85 lpm combined to B50 is equally engine performance with diesel oil. Moreover, syngas flow rate increased to 125 lpm combined to B50 has more engine performance than using B50 and diesel only. However, various emissions are increased as increasing syngas combined to B50.**

***Index Terms*— B50, supercharging syngas, diesel engine, performance, emissions**

I. Introduction

Biodiesel or ester is initially developed as an alternative fuel for the diesel engines to decrease the environmental problem and the respiratory of the human. In Thailand, biodiesel is mixed with diesel at a ratio of 5 to 7% (B5 to B7) replacing to diesel oil nowadays. It is expected that the ratios of biodiesel will be increased to 10% in the future [1]. Other countries of Asia, especially India and Malaysia, are studying the use of diesel oil blended to 50%biodiesel (B50) compared to diesel oil for diesel engines. Because it had a little change of fuel properties, particularly viscosity, density, and heating value, they led to a decrease in the engine performance slightly. The advantages of using B50 is that the various emissions, such as carbon monoxide (CO), hydrocarbons (HC) and black smoke, were significantly reduced [2, 3]. Use of pure biodiesel is challenging in the long term because of the high cost. Moreover, the wear of fuel injection system is quickly increased because of some properties of pure biodiesel affected on the diesel-engine operation [4, 5].

Biomasses are next renewable energy pushed into the widespread usage in this country, but they cannot apply with the diesel engines. There is a method that converts biomasses to syngas by using the gasifiers, and the use of syngas-diesel on dual fuel, where diesel was injected into the cylinder as syngas was introduced through the intake manifold by the mixing box, was the best way and non-modified engines [6-7]. Some researchers [8-10] used various biomasses, such as charcoal, carpentry waste, sawdust, etc., to produce syngas, but synthesis gas generated from charcoal was the best because of lower humidity. Results of engine testing showed that there were the changes in thermal efficiency and emissions (such as CO, HC, and black smoke) which depended on gas flow rate to combine with diesel oil, while diesel saving was increased to 53%. Other researchers [2, 7, 11] produced this gas from else biomasses, such as jatropha seeds, calophyllum inophyllum, and coconut shell, combined to biodiesels synthesized from these plants. The result showed that these emissions were lower while the engine performance was improved, and pilot fuel saving was increased by about 30%. However, the use of pure biodiesel combined to syngas had lower engine performance than using its and diesel only as discussed in Reference [7]. The objective of this work is to study the performance and emissions of a diesel-engine generator using B50 and dual fuel between B50 and supercharging syngas.

II. Methodology

A. Preparation of Syngas

Syngas was generated from a downdraft gasifier by using charcoal biomass and controlling the amount of air by a blower. Specifications of the gasifier are shown in Fig. 1 and Table I (A).

Manuscript received December 25, 2018; revised July 13, 2019.

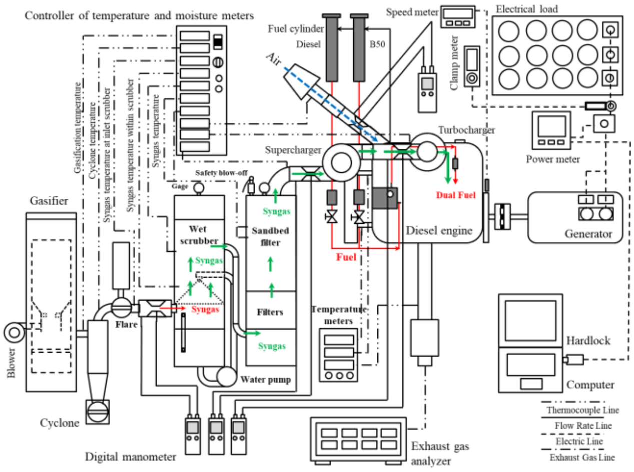

Figure 1. Schematic of the experimental setup.

Before the syngas was sent into a diesel engine, the gas sample was taken to analyze the gas components by using gas chromatography as shown in Table I (B). Syngas was increased the gas flow rate by using the supercharger compressed into a Y-shape mixing box and absorbed by a turbocharger of this engine. For measuring the flow rate of syngas and air, the flow conditioning was installed before the mixing box, and a venturi tube and a digital manometer were applied in this research.

TABLE I. GASIFIER SPECIFICATION AND SYNGAS PROPERTIES

A. Downdraft gasifier specification	
Items	Description
Maximum capacity (kW_{th})	75
Charcoal consumption rate (kg/h)	5 to 6
Maximum gas flow rate (m^3/h)	96 (Charcoal)
Calorific value (MJ/kg)	29.60
Efficiency (%)	70 to 75
B. Syngas properties	
Properties	Volume percentage
Hydrogen (%)	7.5±2.5
Carbon monoxide (%)	29.5±1.5
Carbon dioxide (%)	1.5±0.5
Methane (%)	1.5±0.5
Nitrogen (%)	57.5±2.5
Calorific value (MJ/m^3)	5.08±0.48

B. Preparation of B50

Reactants used the diesel and biodiesel which was palm oil ethyl ester synthesized by transesterification process using oleic palm oil and ethanol using sodium hydroxide. The ratio of diesel and biodiesel was 50:50 %vol, while the mixture process was studied from Ref. [1]. Next, there was the investigating of fuel properties under various ASTM procedures shown in Table II. Properties of B50 compared to diesel show that the kinematic viscosity increased to 51.38%, the fuel density increased to 3.41%, the flash point increased to 65.2 ^oC, the cloud point increased to 3 ^oC, and the lower heating value (LHV) decreased to 7.80%. To compare with the standard diesel as indicated in the results of Reference [12], B50 had the fuel viscosity in the range of 2.5 to 5.7 mm^2/s because this range demonstrated to applying with the fuel injection system of diesel engines. Therefore, the B50 had the kinematic viscosity within the prescribed range and could be used as an alternative fuel in the future.

TABLE II. FUEL PROPERTIES

Properties	ASTM	Diesel	B50
Viscosity (mm^2/sec)	D445	2.90	4.39
Density (kg/m^3)	D1298	821	849
Flash point (^oC)	D93	45.0	110.2
Cloud point (^oC)	D2500	7	10
LHV (MJ/kg)	D240	44.36	40.90

C. Experimental Setup of the Engine Testing

The experiments were carried out on a four-stroke diesel engine [Model, John Deere 3029DF150; engine type, direct injection and turbocharger; cylinder, 3 cyl; capacity, 2.9 L; power (max.), 43 kW @ 2,500 rpm; compression ratio, 17.2.1]. It was connected with an AC generator (20 kW_e) by using the electric lamps to increase the load. Electrical power was measured by a power meter by converting the signal into the richtmass RS485 with USB data converter and hardlock connected with a computer. Temperatures were investigated from the thermocouple connected with the temperature meters. For measuring the emissions, such as CO_2, CO, and HC, they were analzsed from the MOTORSCAN: 8020 eurogas analyzer by using the infrared method.

D. Experimental Procedure

First, the engine was warmed up about 15-20 minutes. After the engine was stable, experiments were started up by using diesel and then B50. Speed was started at 1,000±50 rpm, and it was increased from 1200±50 to 1,600±50 rpm. The amount of both oils was determined at 20 ml to study the fuel consumption rate (FCR). Parameters, such as flow rates, power, temperatures, and emissions, were recorded. Next, syngas was increase to 76 lpm and sent to mix with air in the mixing box. The mixture was, then, sent into the turbocharger and the cylinder where the B50 was separately injected at the normal timing. Again, the engine testing conditions, as well as the recorded parameters, would be the same as those for both oils. After finish using the syngas on duel fuel at a flow rate of 76 lpm, others flow rates of the syngas would, then, be introduced and the same conditions and parameters would be recorded. All the syngas flow rates used in this study were 76, 79, 85, 93, 103, 116, and 125 lpm, and terms were indicated as B50+SG76 lpm, B50+SG79 lpm, B50+SG85 lpm, B50+SG93 lpm, B50+SG103 lpm, B50+SG116 lpm, and B50+SG125 lpm.

III. RESULTS AND DISCUSSION

A. Electrical Power

Figure 2 on the right side indicates that the electrical power increases with increasing speed. Electrical power from using the B50 combined with increasing syngas from 76 to 125 lpm was similar to primary oils, such as B50 and diesel. Because this research was to study the equal power at full load to investigate the change of various parameters as using the dual fuel mode and mode of B50 and diesel only, all engine speed used in this study were 1,000, 1,200, 1,400 and 1,600 rpm. There was the electrical power at 8.817±0.002, 12.264±0.034, 15.847 ±0.002, and 20.273±0.016 kW_e respectively.

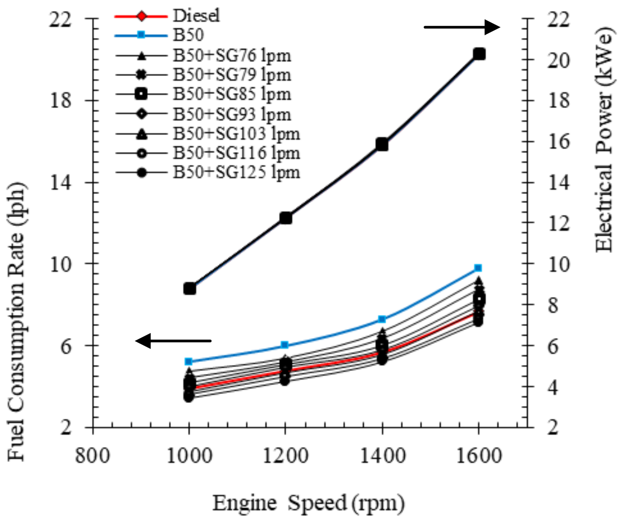

Figure 2. Electrical power and Fuel consumption rate.

B. Fuel Consumption Rate

Figure 2 on the left side shows that FCR increases with increasing speed, while the use of B50 has higher FCR than diesel. At maximum power (1,600 rpm), FCR increased to 13.86% compared with diesel because of lower calorific value [1, 12]. For using B50 combined to compressing syngas (B50+SG) from 76 to 125 lpm, FCR is decreased with increasing syngas. At maximum speed, FCR was decreased from 9.18 to 7.16 lpm while fuel saving was increased from 6.12 to 26.84% compared with using B50 only. Results are consistent with researchers [6, 10] because the use of B50+SG led to the start of combustion faster than the use of both oils only and then there was the reduction of pilot fuel quantity. Results of this research are opposite with Reference [2] because of the higher gas flow rate. Using B50+SG from 75 to 85 lpm could increase the fuel-saving equaled to Diesel, and using B50+SG at 125 lpm had the highest fuel saving.

C. Electrical Efficiency

Figure 3 on the right side demonstrates that the electrical efficiency increases with increasing speed; the maximum efficiency occurs at 1,400 rpm. For using B50 compared with diesel, the electrical efficiency was decreased to 2.41% because of lower fuel heating value [1, 4, 12]. For comparing between B50 with SG (from 76 to 125 lpm at 1,400 rpm) and B50, the electrical efficiency was increased from 1.16 to 6.66%. Results are also opposite with Reference [2], because this research had increased the higher syngas flow rate which led to burning very quickly. As a result, pilot B50 quantity was decreased with increasing gas flow rate. Moreover, this research has found that the use of B50+SG from 79 to 85 lpm is equally electrical efficiency with using diesel only.

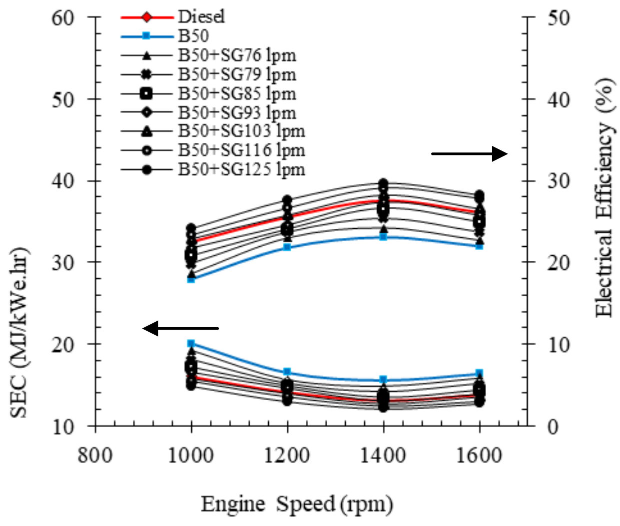

Figure 3. Electrical efficiency and SEC.

D. Specific Energy Consumption

Figure 3 on the left side observes that specific energy consumption (SEC) decreases with increasing speed until maximum efficiency point. For using B50 compared to diesel, SEC was increased to 10.46% at 1,400 rpm. Because the calorific value of B50 was lower than diesel (Table II), this reason led to the increase of B50 quantity [1, 4]. For using B50+SG compared with using B50 only at 1,400 rpm, SEC decreases with increasing syngas as decreased from 14.89 to 12.13 MJ/kW_e.hr. As a result, the energy saving was increased from 4.78 to 22.45%. Results are similar to researchers [6, 10] because supercharging syngas had reduced the pilot B50 quantity. Similarly, using B50+SG from 75 to 85 lpm could decrease the SEC equaled to Diesel and using B50+SG at 125 lpm had the highest energy saving.

E. Exhaust Gas Temperature

Figure 4 on the right side indicates that increasing speed leads to the increase of the exhaust gas temperature (EGT). The investigate at 1,400 rpm, EGT from using B50 is higher as increased to 19.33 ^oC compared to diesel because the high oxygen (O_2) content in B50 led to better complete combustion [1, 4]. Moreover, the use of B50+SG from 76 to 125 lpm has increased the high EGT as increased from 11.47 to 63.33^oC to compare with the use of B50 only. These results are similar to researchers [2, 6, 7] explained from the syngas properties which had the high CO_2 and CO contents (Table I). They led to the increase in combustion temperature in the late combustion phase.

F. Carbon Dioxide Emission

Figure 4 on the left side shows that the release of carbon dioxide (CO_2) is increased with increasing speed. Using B50 compared to diesel at 1,400 rpm found that the CO_2 emission was increased to 1.20%vol because the high O_2 content in B50 improved higher combustion efficiency than diesel [1]. Moreover, the use of B50+SG from 76 to 125 lpm leads to increase of the CO_2 level as increased from 0.63 to 2.35%vol compared to using B50 only at 1,400 rpm. These results are consistent with researchers [2, 6, 7] because the syngas consisted of CO and CO_2 and supercharging syngas reduced the air flow rate sent to the engine. As a result, there was an increase in combustion temperature and the steep rise in the release of CO_2.

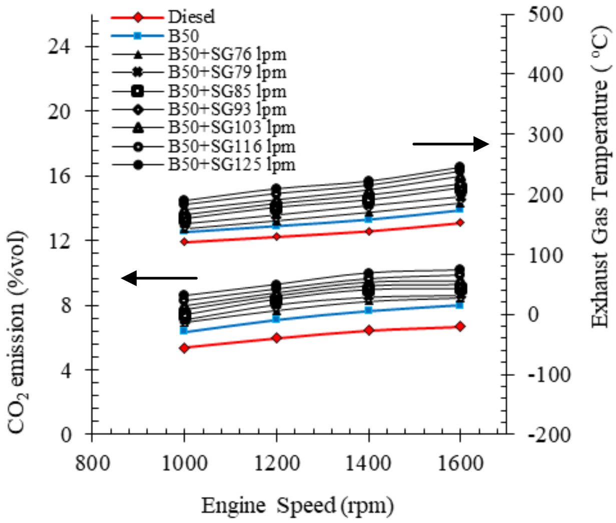

Figure 4. Exhaust gas temperature and CO_2 emission.

G. Carbon Monoxide Emission

Figure 5 on the left side indicates that the carbon monoxide (CO) decreases with increasing speed. Using B50 could reduce the CO emission to 0.13%vol compared to diesel at 1,400 rpm, while this result is similar to Reference [1] because of due to the O_2 content in B50 led to more complete combustion.

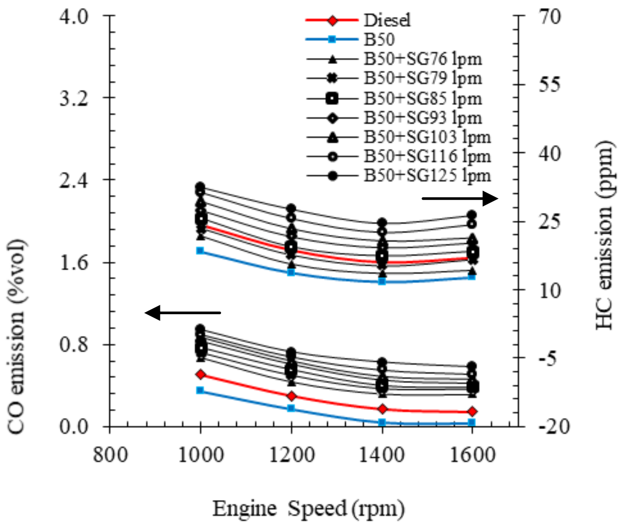

Figure 5. Carbon monoxide and hydrocarbon emissions.

However, the results of CO release are changed as using B50+SG by the CO emission increases with increasing syngas. Using B50+SG from 76 to 125 lpm at 1,400 rpm shows that the CO emission increased from 0.28 to 0.59%vol compared with using B50 only. Results are consistent with researchers [2, 6, 7] because the more syngas was compressed to the intake manifold and the decrease of air flow to the engine as well as the amount of O_2 required for complete combustion was decreased.

H. Hydrocarbon Emission

Figure 5 on the right side shows that the emission of hydrocarbon (HC) decreases with increasing speed, while the use of B50 is lower HC emission than diesel as decreased to 4.22ppm at 1,400 rpm. This HC reduction may be due to the high O_2 content in B50 led to better complete combustion [1]. On the other hand, using B50 +SG from 76 to 125 lpm has adverse effects. HC emission was increased from 2 to 13 ppm to compare with using B50 only. These results are consistent with researchers [2, 6, 7]. The cause of increasing HC emission is explained from the direct result of incomplete combustion because the syngas contains the innumerable molecules of C and H which led to the fuel-rich mixture combustion.

IV. CONCLUSION

For the operation of a turbocharging diesel-engine generator using the B50 and the dual fuel between supercharging syngas and B50, results of performance and emission characteristics are summarized as follows.

- For applying the B50 with the diesel engine, the electrical efficiency from using B50 is lower than using diesel. Since B50 had a lower calorific value, therefore, the fuel consumption and SEC would slightly increase. However, there is a remarkable decrease in the CO and HC emissions, and it could be applied as a replacement fuel with the diesel engines in the future.
- The possibility of using B50 combined to compressing syngas on dual fuel compared with only B50 indicates that there was the increase of the electrical efficiency up to 6.66%, and the decrease of the fuel consumption led to fuel saving increased to 26.84% as compressing syngas up to 125 lpm.
- Results from measuring the various emissions show that the CO_2 level increased with increasing syngas as consistent with the increase of exhaust gas temperature. As syngas is increased to 125 lpm, the amount of the air is decreased very much. Hence, the formation of pollutions, such as CO and HC, are released galore because of the less complete combustion.

To further improve the present system, the following suggestions can be adopted in the future.

- Study of the combustion and emissions characteristics and the engine wear from using B50 and compressing syngas on dual fuel in the long term.
- Using supercharged air and syngas to improve engine performance and to decrease the CO, HC, and black smoke emissions.

- Using other biomasses to produce the syngas fuel and method of tar removal.

ACKNOWLEDGMENT

The authors wish to thank A. Jiw, K. Nukul, and W. Boonmak for collected experimental data. The financial support from the Faculty of Engineering, Burapha University, Thailand The financial support from the Faculty of Engineering, Burapha University, Thailand (Grant No. 412/2561,6/2559) is gratefully acknowledged.

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