Using Diesohol and Supercharging Syngas on Dual Fuel in a Turbocharging Diesel-engine Generator

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***Abstract*— Developing diesohol, the diesel mixed to ethanol and emulsifiers, is interesting nowadays because of a non-complex method and low cost. Moreover, the study of using diesohol combined to syngas has a few pieces of research. The main objective of this research is to study the use of diesohol combined to supercharging syngas from gas flow rate 76 to 125 lpm on dual fuel with a turbocharging diesel-engine generator. Engine speed was adjusted from 1,000 to 1,600 rpm at full load. Syngas was produced from a downdraft gasifier, as charcoal biomass was used the primary fuel. Results of engine testing confirmed that engine performance was decreased as emissions were also decreased to use diesohol only. On the other hand, use of diesohol combined to compressing syngas up to 125 lpm on dual fuel mode was more engine performance than using this oil only, and the fuel saving was increased to 22.83% at 1,600 rpm. The emission compositions in the exhaust gas were enormously increased with increasing syngas quantity.**

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

I. Introduction

Ethanol is an alternative fuel interesting nowadays because of the oxygen (O_2) concentration into its which led to decreasing of the pollutants of diesel engines, such as carbon monoxide (CO), hydrocarbons (HC) and black smoke. For the use of ethanol with diesel engines, the best way is to use diesel blended with ethanol and emulsifiers by emulsion method which called diesohol. It had the best stability and non-modified engines [1]. Reference [2] explained about the use of diesohol, which came from the 90% of diesel mixed with 10% of ethanol and emulsifiers, such as ethyl acetate, butanol, biodiesels, etc. It had one of the best stability with very little and almost unseen stratification. While ethyl acetate was an emulsifier produced from the esterification of ethanol with acetic acid, the benefit of this emulsifier was that cheap and easy to find. Researchers [1-2] concluded that the use of 90% diesel mixed to 5% ethanol and 5% ethyl acetate had similar fuel properties to diesel that showed higher fuel consumption and released lower CO and smoke emissions.

Biomasses are another type of renewable energy pushed into widespread usage in Thailand, but they cannot apply with engines. There is the best way to convert biomasses to syngas fuel by using the gasification method as studied in Reference [3]. Use of syngas-diesel on dual fuel, where diesel was injected as a pilot fuel to initiate the ignition as syngas was introduced through the intake manifold by the mixing box, was the best way and non-modified engines [4]. Some researchers [5-7] used various biomasses, such as charcoal, sugarcane bagasse, carpentry waste, etc., to produce syngas, but syngas 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, while diesel saving was increased to 53%. Other researchers [8-12] produced this gas from else biomasses, such as jatropha seeds, calophyllum inophyllum, coconut shell, etc., combined to biodiesels synthesized from these plants. These pollutants were lower, specific energy consumption was improved, and pilot fuel saving was increased by about 30%.

Biodiesel has more complicated method than diesohol and the use of diesohol and syngas are little research. The objective of proposed work is to study the performance and emissions of a diesel-engine generator from using diesohol only and dual fuel between diesohol and supercharging syngas.

II. Methodology

A. Syngas as a Potential Fuel

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 November 5, 2018; revised July 26, 2019.

doi: 10.18178/ijmerr.8.6.972-976

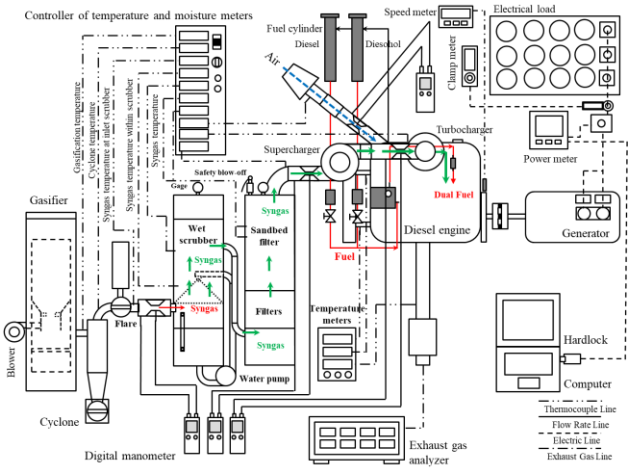

Figure 1. Schematic of the experimental setup.

Before the syngas was sent into a diesel engine, the gas sample was taken to analyse the gas components by using a 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 Diesohol

Diesohol was synthesized by the emulsion method, while reactants used the diesel, ethanol (99.9%w) and ethyl acetate. The ratio of diesel: ethanol: ethyl acetate was 90:5:5 %vol as studied from Reference [1-2]. Next, there was the investigating of fuel properties under various ASTM procedures shown in Table II. Properties of diesohol compared to diesel show that kinematic viscosity decreased to 22.41%, fuel density decreased to 1.22%, flash point decreased to 32 °C, and lower heating value (LHV) decreased to 7.26%. As consistent with Reference [1], it is explained by the physical properties of these alcohols were lower than diesel.

TABLE II. FUEL PROPERTIES

Items	ASTM	SD	Diesel	Diesohol
Viscosity (mm^2/s)	D445	1.80-4.10	2.90	2.25
Density (kg/m^3)	D1298	810-870	821	811
Flash point (°C)	D93	52 min	45	13
LHV (MJ/kg)	D240	-	44.36	41.14

Besides, this oil is compared with the characteristics and qualities of standard diesel (SD) in 2013 as announced by the Department of Energy Business as studied from Reference [2], it indicates that diesohol had the kinematic viscosity and fuel density within the prescribed range and could be applied as a replacement fuel with the diesel engines in the future.

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 analysed 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 engine was stable, experiments were started up by using diesel and then diesohol. 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 diesohol 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 Diesohol+SG76 lpm, Diesohol+SG79 lpm, Diesohol+ SG85 lpm, Diesohol+SG93 lpm, Diesohol+SG103 lpm, Diesohol+SG116 lpm, and Diesohol+SG125 lpm.

III. RESULTS AND DISCUSSIONS

A. Electrical Power

Fig. 2 on the right side indicates that the electrical power increases with increasing speed. Electrical power from using the diesohol combined with increasing syngas

from 76 to 125 lpm was similar to primary oils, such as diesohol and diesel. Because this research was to study the equally power at full load to investigate the change of various parameters as using the dual fuel mode and mode of diesohol 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 11.28±0.08, 15.02±0.03, 17.35±0.04, and 20.70±0.19 kW_e respectively.

B. Fuel Consumption Rate

Fig. 2 on the left side demonstrates that FCR increases with increasing speed, while using diesohol has higher FCR than diesel. At maximum power (1,600 rpm), the FCR was increased to 13.18% compared with diesel because of lower fuel heating value than diesel [1-2]. Whereas, the use of diesohol combined to increasing syngas from 76 to 125 lpm compared to using diesohol and diesel oils only show that FCR decreases with increasing syngas at all speeds. At maximum power, FCR was reduced from 7.16 to 5.96 lpm while fuel saving was increased from 7.26 to 22.83% compared with using diesohol only, respectively.

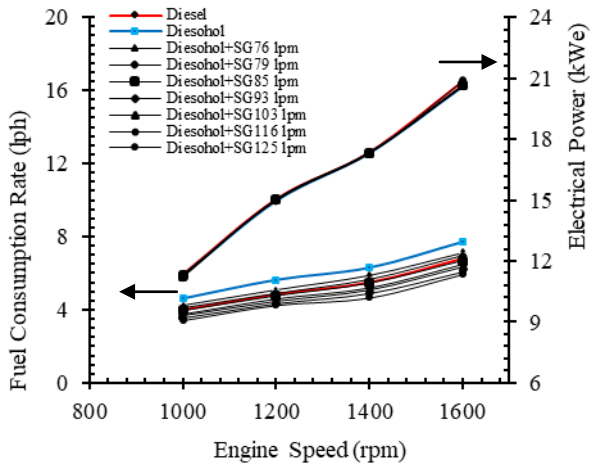

Figure 2. Electrical power and fuel consumption rate.

This research has found that using diesohol+SG125 lpm had the most fuel saving. These are consistent with Reference [3] because the use of diesohol combined with increasing syngas was ignited faster than the use of diesohol and diesel oils only, it led to opening and closing of needle lift into an injector quickly and the reduction of pilot fuel quantity.

C. Electrical Efficiency

Fig. 3 on the right side shows that the highest electrical efficiency occurs at 1,400 rpm. For using diesohol compared with diesel at maximum efficiency, electrical efficiency is slightly lower as decreased to 0.93% because of lower fuel heating value than diesel [2]. For increasing syngas to combine with diesohol in dual fuel mode compared with using diesohol only, the electrical efficiency increases from 1.18 to 8.37 % with increasing syngas flow rate from 76 to 125 lpm. This result is similar to the outcome of Reference [3], while it is clarified by better combustion of relatively rich syngas-air mixture affected on quickly premixed combustion phase and better combustion of the premixed mixture of diesohol and syngas on dual fuel resulting in the reduced requirement of total energy input.

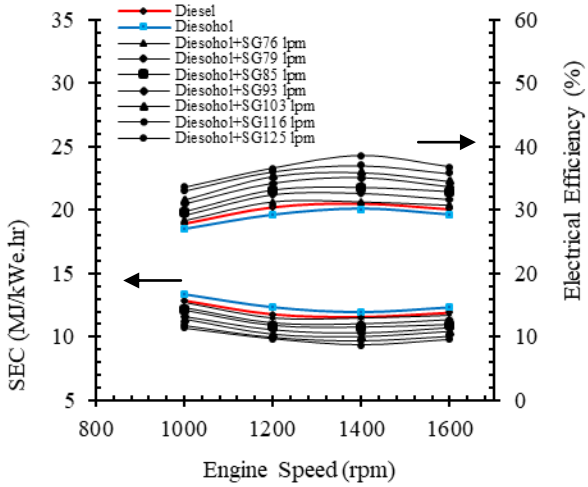

Figure 3. Electrical efficiency and SEC.

D. Specific Energy Consumption

Fig. 3 on the left side observes that specific energy consumption (SEC) decreases with increasing speed, and the lowest SEC occurs at 1,400 rpm. For using diesohol compared to diesel, SEC is slightly higher as increased to 3.31% at minimum SEC. This result is consistent with the conclusion of Reference [2] explained by the diesohol was lower fuel heating value than diesel. However, the SEC is decreased as increasing syngas combined with diesohol in dual fuel mode. At minimum SEC, the SEC declined from 11.49 to 9.35 MJ/kWe.hr. As a result, energy saving increased from 5.09 to 20.56% compared with diesohol only, respectively. Results are consistent with the References [3-4], because supercharging syngas led to the increase of fuel replacement.

E. Exhaust Gas Temperature

Fig. 4 on the right side shows that the exhaust-gas temperature (EGT) increases with increasing speed. At maximum efficiency, the EGT of diesohol is lower than diesel as decreased to 5 ^{o}C. This result is consistent with researchers [1-2] because the higher latent heat of evaporation of diesohol led to the decrease of combustion temperature. However, compressing syngas combined to this oil to compare with using oils, diesohol, and diesel, only indicates that the EGT increases with increasing gas flow rate as increased from 9 to 49 ^{o}C compared with the only diesohol. These results are similar to researchers [3, 9] explained from the syngas properties which had the high CO_2 and CO contents (Table I). They led to the increase of combustion temperature in the late of combustion phase.

F. Carbon Dioxide Emission

Fig. 4 on the left side proves that the release of carbon dioxide (CO_2) is increased with increasing speed. The reduction of CO_2 emission, at maximum efficiency, by using diesohol compared to diesel, was decreased to 0.31 %vol. It is consistent with References [1-2] because

of the lower burning temperature from the high latent heat of ethanol-ethyl acetate vaporization.

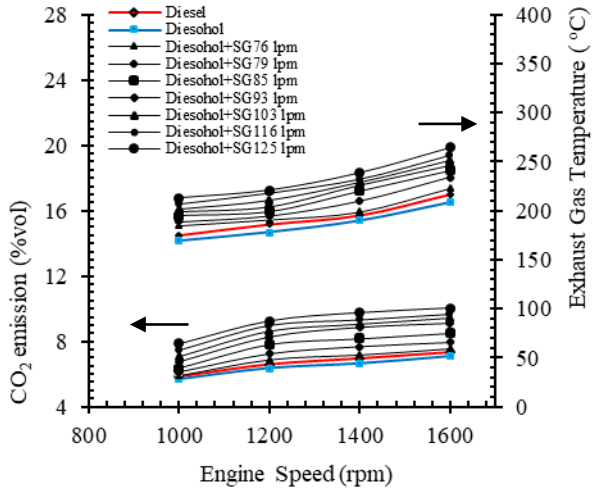

Figure 4. Exhaust gas temperature and CO_2 emissions.

However, this research demonstrates that compressing syngas combined to diesohol has increased the level of CO_2 very high. Upon comparing with using diesohol, at maximum efficiency, the CO_2 emission was increased from 0.54 to 3.11%vol. Results are similar to References [4, 9], because the syngas consisted of CO and CO_2 and supercharging syngas reduced the air flow rate sent to the engine. Although diesohol had the more O_2 content, the innumerable content of C was burned with less O_2. As a result, there was an increase in the release of CO_2 [13].

G. Carbon Monoxide Emission

Fig. 5 on the left side indicates that the carbon monoxide (CO) decreases with increasing speed. Using diesohol could reduce CO emission to 0.05 %vol compared to diesel at maximum efficiency, which is agreed by References [1-2] due to the O_2 content in diesohol led to more complete combustion.

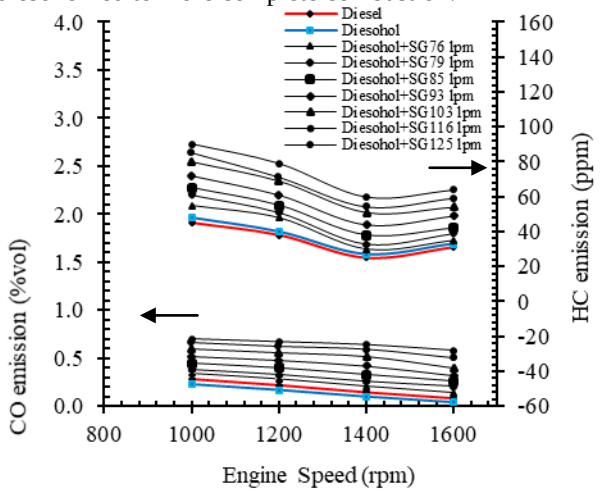

Figure 5. Carbon monoxide and hydrocarbon emissions.

However, the results of CO release are changed as increasing syngas combined to diesohol. CO emission highly increases with increasing syngas. As compared with diesohol only at maximum efficiency, CO emission has risen from 0.11 to 0.54 %vol while results are similar to References [4, 9, 13, 14]. It is hypothesized by the incomplete combustion from the highest presence of CO from syngas compositions (Table I) burned with with less O_2 content.

H. Hydrocarbon Emission

Fig. 5 on the right side shows that the emission of hydrocarbon (HC) decreases with increasing speed, while using diesohol is higher HC emission than diesel and increased to 2 ppm at maximum efficiency. It was hypothesized due to the higher heat of evaporation of the ethanol-ethyl acetate blend that increases the emission of HC [1-2]. Moreover, using diesohol and compressing syngas have increased the HC emission with increasing syngas as risen from 3 to 33 ppm to compare with using diesohol only. It 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 [13-15].

IV. Conclusion

The possibility of the use of diesohol combined with supercharging syngas compared to using this oil only for this engine can be summarized as follows:

- Use of diesohol has slightly lower engine performance. However, various emissions are decreased to use this oil because of the O_2 content in diesohol which resulted in more complete combustion than diesel.
- Results of the engine performance using the dual fuel mode between diesohol and compressing syngas was confirmed that the use of diesohol combined to syngas (up to 125 lpm) had improved the engine performance more than using this oil only; increasing syngas up to 125 lpm, fuel, and energy saving were increased to 22.83% and 20.56% respectively.
- For investigating the level of CO_2, CO, and HC releases, they are increased with increasing syngas flow rate although there is the increase of O_2 content from diesohol to combine with syngas on dual fuel.

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

- Study of using supercharged air combined with compressed syngas to improve engine performance and to decrease emissions, such as CO, HC, and black smoke.
- Study of increasing ethanol with of other emulsifiers, especially biodiesel that would improve the fuel properties similar to diesel combine with syngas on dual fuel mode to be the renewable energy on the agriculture sector in the future.

Acknowledgment

The authors wish to thank C. Lerdphukaew, N. Panlai and W. Ruxsasin for collected experimental data. This

work was supported by the Faculty of Engineering, Burapha University, Thailand (Grant No. 394/2561) is gratefully acknowledged.

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