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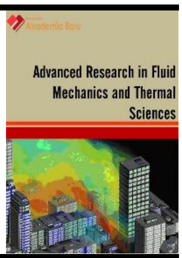

The Performance and Electricity Cost of Generator Engine Using Ethanol-Methanol Blend

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ABSTRACT

Ethanol is an example of renewable energy; however, its price is still expensive. The blend of ethanol and cheaper methanol is interesting to study for electricity generation. The aim of this study is to investigate the performance of generator engine and the electricity cost by using the ethanol-methanol blend fuel. The study was carried out experimentally in the generator set with a capacity of 3000 W where the electricity load was varied from 100 W to 3000 W. The result shows that the highest efficiency of generator engine is 26.33% at 2500 W load @ 2930 rpm and the lowest specific fuel consumption is 0.778 kg/kWh at 2500 W load @2930 rpm. At the highest efficiency, the cost of electricity is 18,945 IDR/kWh or 1.34 USD/kWh. Furthermore, it is interesting to further study the enhancing strategy for efficiency and the reducing cost of the electricity generation.

1. Introduction

Alternative fuels as a substitute for fossil fuels have been developed for years, one of them is alcohol. Ethanol is an example of alcohol. Ethanol can be produced from the fermentation of sugar and water solutions. Ethanol has a fairly high octane number, which is 106 to 110 [1] so it is suitable if used as fuel for gasoline engines. Ethanol has a very small cetane number (5-8), so it cannot be used as diesel motor fuel [2]. However, ethanol can still be used as a component of the fuel mixture.

Another form of alcohol is methanol. This kind of alcohol can be obtained at a lower price. Methanol is a simpler alcohol than ethanol. It consists of a methyl group connected to a hydroxyl group (CH_3OH) while the ethanol consists of an ethyl group connected to a hydroxyl group (C_2H_5OH). Methanol has a lower heating value (20.1 MJ/kg) than ethanol (26.8 MJ/kg). As methanol has lower price than ethanol, it is interesting to study for electricity generation.

The gasoline engine needs a fuel with high octane number, high auto-ignition temperature, and low cetane number to be worked. The octane number, auto-ignition temperature, and cetane

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number of ethanol are 106-110 [1], 365 °C [3], and 5-8 [2], respectively. The octane number, auto-ignition temperature, and cetane number of methanol are 109 [4], 470 °C [5], and 5 [6], respectively. Both methanol and ethanol can be used in gasoline engines. There are two things to consider when using ethanol in a gasoline motor, the heating value and the air fuel ratio. Compared to gasoline, ethanol has a lower heating value. At the time of combustion, ethanol requires far less air than gasoline, which is 9 and 14.7, respectively [7]. The aim of this study is to investigate the performance of generator engine and the electricity cost by using the ethanol-methanol blend fuel. Furthermore, it is interesting to further study the enhancing strategy for efficiency and the reducing cost of the electricity generation.

2. Methods

The generator engine consists of an internal combustion engine motor and an electricity generator. Its function is to convert energy from fuel into electric energy. The motor converts fuel energy into mechanical energy, then the generator converts mechanical energy to electric energy. The type of generator set used is Oshima OH5500HE with OHV (Over Head Valve) which has 4 stroke, 1 cylinder, 600 cm^3 engine oil capacity, 15 liters of fuel tank capacity, with automatic voltage regulator, and a maximum output power of 3000 W and rated power output of 2800 W. The compression ratio is 8.5: 1 and has a combustion chamber volume of 160 cc. The maximum torque is 10.8 Nm. The current released from the generator has an AC voltage of 220 V with a frequency of 50 Hz.

The considered performances were efficiency and specific fuel consumption. The load varied from 100 W to 3000 W. The efficiency was calculated by using the known lower heating value. As the mixture consists of methanol, ethanol and water, the lower heating value can be seen in the Table 1.

Table 1
The properties of mixture

	Methanol	Ethanol	Mixture
Concentration (v/v)	86.52%	9.97%	100%
Density (kg/m3)	792	785	842
Concentration (m/m)	81.39%	9.30%	100%
LHV (MJ/kg)	20.1	26.8	18.85

The efficiency of the generator system can be defined as the ratio between the power produced and the fuel flow rate multiplied by the lower heating value of the fuel used [8]. The efficiency formula can be seen in Eq. (1). Efficiency is influenced by several things, including the type of fuel used (heating value of the fuel) and the compression ratio.

$$\eta = P/(\dot{m} \times LHV) \quad (1)$$

Specific Fuel Consumption is the ratio between the amount of fuel used (kg) and the energy produced (kWh), or equal to the ratio between the instantaneous fuel flow rate and the power produced [8]. To calculate the energy produced by the generator, a digital multimeter was placed between the generator engine and the load (see Figure 1). The specific fuel consumption formula could be seen in Eq. (2).

$$SFC = m/(P \times t) \quad (2)$$

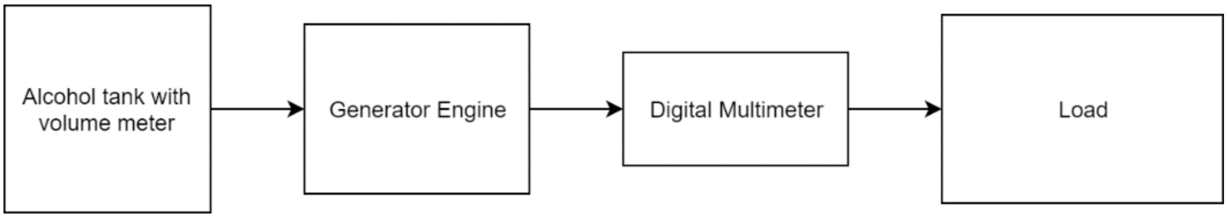

Fig. 1. The scheme of the experiment

The digital multimeter was placed between the engine and the load. The digital multimeter used is DL69-2047. This tool can measure power, energy, cos ϕ, voltage, and current. The specifications are as follows, the highest power is 30000 W, the maximum energy is 99999 kWh, the maximum current strength is 100 A, and the maxi-mum voltage is 300 V. The load circuit consisted of a series of bulb lamps as loads arranged in series and parallel and several switches. The mounted bulb consisted of 25 bulbs each 100 W and 4 bulbs each 200 W.

The alcohol tank was equipped with a volume meter (graduated cylinder) to determine the amount of alcohol used during combustion. The alcohol enters the combustion chamber to be converted into mechanical energy, then the generator converts motion energy into electric energy. The electric energy was loaded in the form of light bulb variations. The energy used (kWh), voltage (V), current (A), and power (W) were measured.

The processes of gathering the data are as follows. First, it was arranging the equipment according to the scheme in Figure 1. The next step was turning on the generator set without load with alcohol fuel, then leaving it for 20 minutes. This means to create steady state conditions. After that, it was needed for setting the load to 100 W, then measuring the initial volume of alcohol, and turning on the stopwatch for 5 minutes. The next step was measuring the power, voltage, current, and motor rotational speed. The last step after 5 minutes was measuring the final volume of alcohol. To get the curve of efficiency and specific fuel consumption to the engine load or the power generated, it was needed to repeat those steps at higher load up to its maximum capability.

3. Results and Discussion

Analyzing the composition of compounds in alcohol fuels was done by using a Gas Chromatography (GC) tool. This test was conducted at the Laboratory of Analysis and Instrumental at the UGM Chemical Engineering Department. Analyzing the composition of compounds in alcohol fuel is carried out on a Gas Chromatography tool where the sample was sufficiently accommodated in a closed container (bottle) so that the liquid does not evaporate. The Gas Chromatography specification could be seen in Table 2.

Table 2
The Gas Chromatography specification

GC-14B Shimadzu	
Gas Carrier	N_2
Flow Rate	2 ml/minute
Column Temperature	100 °C
Detector Temperature	150 °C

The Gas Chromatography produced a voltage curve graph (μV) to retention time (minutes) as can be seen in Figure 2. Every peak in the graph indicates that there is one compound in the sample. Then to find out the v/v content of the compound, the peak area was needed to be calculated. The peak area was then compared to the external standard area of the compound, so a percentage was obtained where this percentage was the v/v level of the compound against the sample.

In Figure 2, there are two peaks on the monogram at 5.469 and 6.317 minutes. Figure 2 shows two peaks which state that there are two compounds in the sample. The first peak is the peak owned by methanol while the second peak is the peak owned by ethanol. Based on the area of the two peaks, the amount of methanol content is 86.52%, ethanol content is 9.97%, and the rest is water. With this level, the calorific value of alcohol can be calculated at 18.85 MJ/kg.

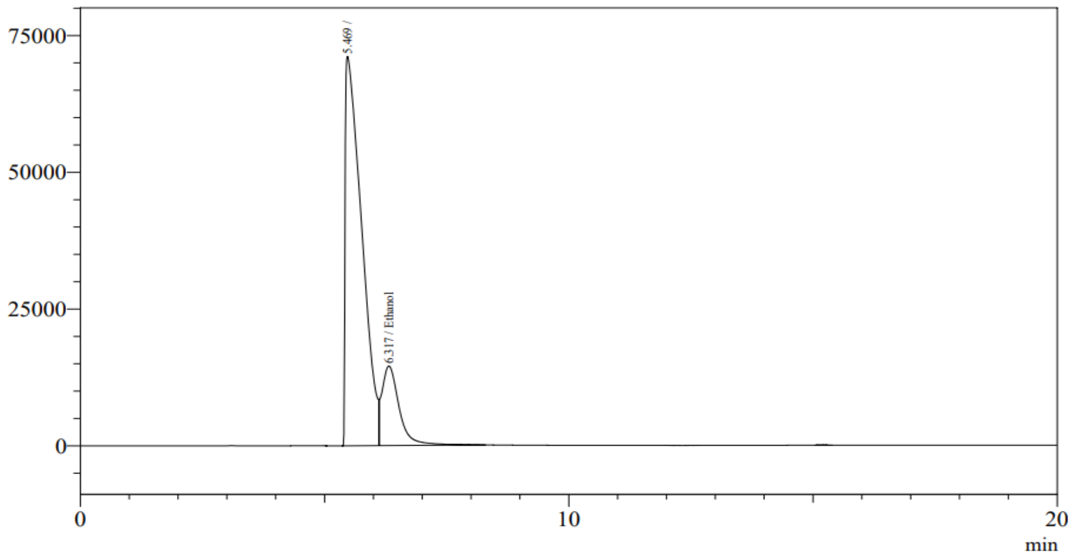

Fig. 2. The chromatogram of ethanol-methanol blend

Retention time is a qualitative aspect of a chromatogram, and the retention time of a compound will always be the same under identical chromatographic conditions [9]. Therefore, every gas chromatography has its own standards. The intended standards include standards of retention time, area and concentration.

The relationship between specific fuel consumption and efficiency to the power generated can be seen in Figure 3 and Figure 4. It can be seen that the efficiency of the engine rises with the increase of the power generated. The specific fuel consumption is inversely proportional to the efficiency. As the generated power increases, the specific fuel consumption decreases. At certain load, the efficiency of the engine decreases in conjunction with the increasing of specific fuel consumption.

The phenomenon that occurs with specific fuel consumption is different from the phenomenon in efficiency. The higher the power from 100 W to 800 W, SFC decreases dramatically and reaches a minimum at engine speed of around 2500 W. The lowest SFC can be interpreted as the lowest ratio of the power generated by the combustion engine to the fuel required. At low load, the required alcohol fuel is low. The higher the power generated by the engine, the fuel that enters the combustion chamber also increases. Meanwhile, at a low load of 100 W, the consumed fuel is not so low so that the specific fuel consumption is high.

In Figure 4, it can also be seen that the best specific fuel consumption is at a rotational speed of 2500 W with the acquisition of 0.73 kg/kWh. The minimum specific fuel consumption in this test that is using alcohol fuel is worse compared to other studies of 0.40 kg/kWh [10] which used ethanol fuel. The lowest specific fuel consumption in this study is also worse than the lowest SFC with methanol fueled engine at a compression ratio of 10, that is 0.5912 kg/kWh [11]. It can be noted that the current engine has compression ratio of 8.5.

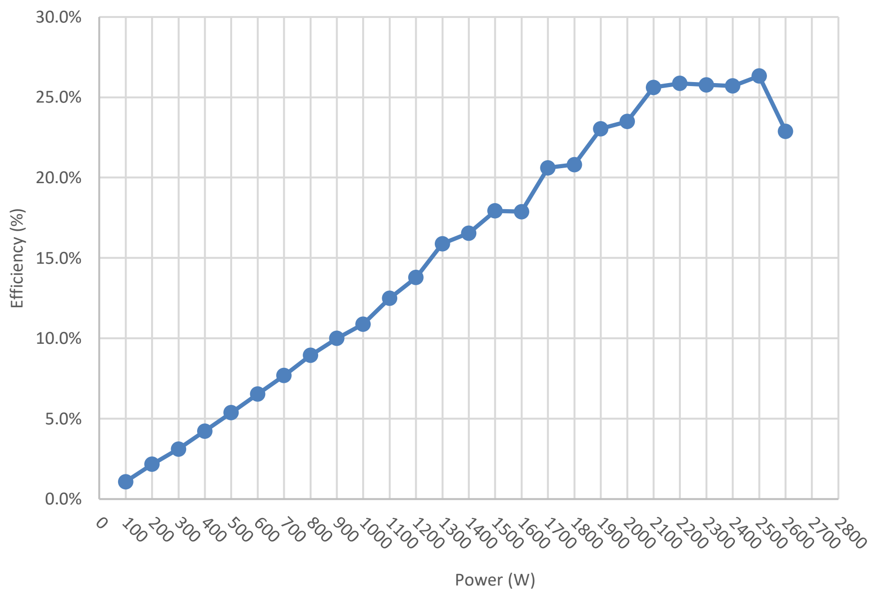

Fig. 3. Engine efficiency

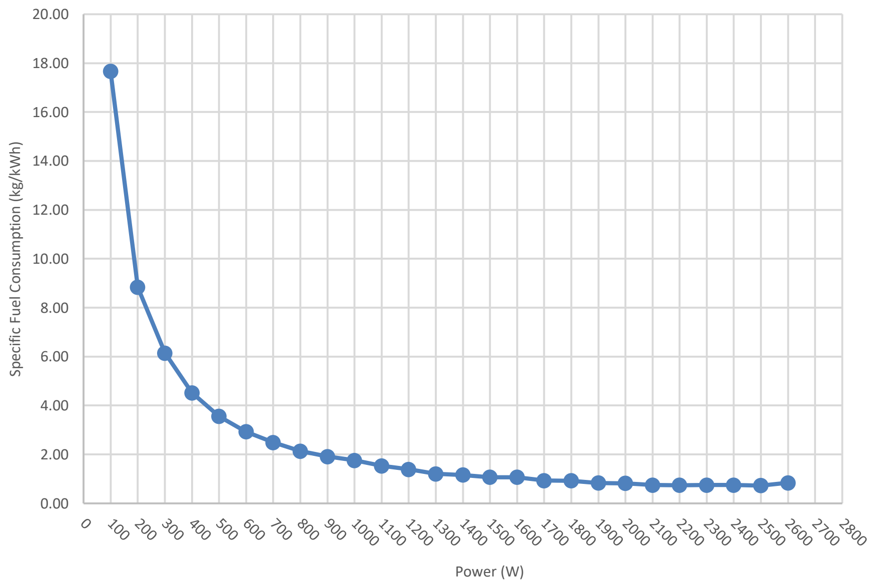

Fig. 4. Specific fuel consumption of engine

Specific fuel consumption is inversely proportional to efficiency, where the value will increase with increasing load, but will decrease at certain load points, also applies to increased engine speed. The motor in the generator cannot reach the engine speed below 2000 rpm, if it happens then the motor turns on unstable or fluctuations in engine speed. This happens because at low rotation, the quality of the mixture of fuel and air so that the combustion is bad [10].

In Figure 3, it can be obtained that the highest efficiency of alcohol-fueled generators is 26.3% at load of 2500 W. This peak efficiency is lower compared to methanol and ethanol fueled engines, which is 43% and 42% [12], and is also lower compared to general SI engine fueled with gasoline, which is around 30% to 35% [13]. Other researchers stated that the efficiency of electricity generator fueled by gasoline is 21% which is lower [14]. This is due to the existence of electricity generator which converts mechanical energy into electrical energy. The electricity generator itself has a certain efficiency, so the overall efficiency surely decreases. It is generally known that the flame speed of methanol is much higher than the hydrocarbon fuels. This flame speed causes more complete combustion resulting in low specific fuel consumption and high efficiency [11]. The next reason is because alcohol fuels containing methanol and ethanol have a higher oxygen content than those of hydrocarbon fuels [15], so they can improve the quality of combustion. In addition, the evaporation heat from methanol is also high so that it is able to absorb heat in the cylinder during the compression stroke and is able to increase overall engine efficiency [11]. The efficiency of this alcohol-fueled generator set is also higher compared to gasoline fuel because alcohol has a high heat of evaporation.

In Indonesia, the lowest price of this kind of alcohol could be found at 20,500 IDR /liter. As the minimum specific fuel consumption is 0.778 kg/kWh, the cost of electricity is 18,945 IDR/kWh or 1.34 USD/kWh or 1.22 EUR/kWh at the maximum efficiency. The cost of electricity from lignite at 10.75 Eurocent/kWh, from hard coal 8.94 Eurocent/kWh, from natural gas 4.91 Eurocent/kWh, from photovoltaic 1.18 Eurocent/kWh, from wind 0.26 Eurocent/kWh and from hydro 0.18 Eurocent/kWh [16]. Previous researchers noted that the fuel cost using diesel as fuel is 0.282 USD/kWh [17]. Other researchers stated that the fuel cost using bioethanol as fuel is 0.324 USD/kWh and diesel as fuel is 0.057 USD/kWh [18]. The cost of electricity from ethanol-methanol blend in this research is considered high, compared to the mentioned above. This is due to the lower heating value of the ethanol-methanol blend is considered low compared to its price.

4. Conclusions

It could be concluded that the increasing load caused the efficiency to increase and decreasing SFC. At certain load, the efficiency started to decrease and the specific fuel consumption started to increase. The highest efficiency, and the lowest specific fuel consumption are 26,3% and 0,73 kg/kWh respectively. As currently in Indonesia the price of this kind of alcohol is 20,500 IDR, so at the maximum efficiency the cost of electricity is 18,945 IDR/kWh or 1.34 USD/kWh or 1.22 EUR/kWh.

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References
[1] Chansauria, Prakhar, and R. K. Mandloi. "Effects of ethanol blends on performance of spark ignition engine-a review." *Materials Today: Proceedings* 5, no. 2 (2018): 4066-4077. https://doi.org/10.1016/j.matpr.2017.11.668
[2] Xing-cai, Lü, Yang Jian-Guang, Zhang Wu-Gao, and Huang Zhen. "Effect of cetane number improver on heat release rate and emissions of high speed diesel engine fueled with ethanol-diesel blend fuel." *Fuel* 83, no. 14-15 (2004): 2013-2020. https://doi.org/10.1016/j.fuel.2004.05.003
[3] Engineering Toolbox. "Fuels and Chemicals - Autoignition Temperatures." *The Engineering Toolbox*, 2003. https://www.engineeringtoolbox.com/fuels-ignition-temperatures-d_171.html.
[4] Wang, Chongming, Yanfei Li, Cangsu Xu, Tawfik Badawy, Amrit Sahu, and Changzhao Jiang. "Methanol as an octane booster for gasoline fuels." *Fuel* 248 (2019): 76-84. https://doi.org/10.1016/j.fuel.2019.02.128
[5] Alliance Consulting International. “Methanol Safe Handling Manual.” Methanol Institute (2008): 1-37.
[6] Li, Ruina, Zhong Wang, Peiyong Ni, Yang Zhao, Mingdi Li, and Lilin Li. "Effects of cetane number improvers on the performance of diesel engine fuelled with methanol/biodiesel blend." *Fuel* 128 (2014): 180-187. https://doi.org/10.1016/j.fuel.2014.03.011

[7] Ilves, Risto, Arne Küüt, and Jüri Olt. "Ethanol as Internal Combustion Engine Fuel." In *Ethanol*, pp. 215-229. Elsevier, 2019.
https://doi.org/10.1016/B978-0-12-811458-2.00008-0

[8] Silva, Felipe Pinheiro, Samuel Nelson Melegari de Souza, Danilo Sey Kitamura, Carlos Eduardo Camargo Nogueira, and Rodrigo Bueno Otto. "Energy efficiency of a micro-generation unit of electricity from biogas of swine manure." *Renewable and Sustainable Energy Reviews* 82 (2018): 3900-3906.
https://doi.org/10.1016/j.rser.2017.10.083

[9] Chromacademy. "Theory and Instrumentation of GC - Introduction." LC/GC's CHROMacademy (2014).

[10] Duy, Vinh Nguyen, Khanh Nguyen Duc, Doan Nguyen Cong, Hoi Nguyen Xa, and Tuan Le Anh. "Experimental study on improving performance and emission characteristics of used motorcycle fueled with ethanol by exhaust gas heating transfer system." *Energy for Sustainable Development* 51 (2019): 56-62.
https://doi.org/10.1016/j.esd.2019.05.006

[11] Celik, M. Bahattin, Bülent Özdalyan, and Faruk Alkan. "The use of pure methanol as fuel at high compression ratio in a single cylinder gasoline engine." *Fuel* 90, no. 4 (2011): 1591-1598.
https://doi.org/10.1016/j.fuel.2010.10.035

[12] Brusstar, Matthew, Mark Stuhldreher, David Swain, and William Pidgeon. "High efficiency and low emissions from a port-injected engine with neat alcohol fuels." *SAE Transactions* (2002): 1445-1451.
https://doi.org/10.4271/2002-01-2743

[13] Kutlar, Osman Akin, Hikmet Arslan, and Alper Tolga Calik. "Methods to improve efficiency of four stroke, spark ignition engines at part load." *Energy Conversion and Management* 46, no. 20 (2005): 3202-3220.
https://doi.org/10.1016/j.enconman.2005.03.008

[14] Hassan, Suhaimi, and Hamdan Ya. "Experimental Study on Electrical Power Generation from a 1-kW Engine Using Simulated Biogas Fuel." In *Rotating Machineries*, pp. 93-104. Springer, Singapore, 2019.
https://doi.org/10.1007/978-981-13-2357-7_7

[15] Balki, Mustafa Kemal, Cenk Sayin, and Mustafa Canakci. "The effect of different alcohol fuels on the performance, emission and combustion characteristics of a gasoline engine." *Fuel* 115 (2014): 901-906.
https://doi.org/10.1016/j.fuel.2012.09.020

[16] Schwermer, Sylvia, Philipp Preiss, and Wolf Müller. "Best-Practice-Kostensätze für Luftschadstoffe, Verkehr, Strom- und Wärmeerzeugung." *Anhang B der "Methodenkonvention* 2 (2013).

[17] Gioutsos, Dean Marcus, Kornelis Blok, Leonore van Velzen, and Sjoerd Moorman. "Cost-optimal electricity systems with increasing renewable energy penetration for islands across the globe." *Applied Energy* 226 (2018): 437-449.
https://doi.org/10.1016/j.apenergy.2018.05.108

Timmons, D., A. Z. Dhunny, K. Elahee, B. Havumaki, M. Howells, A. Khoodaruth, A. K. Lema-Driscoll et al. "Cost minimization for fully renewable electricity systems: A Mauritius case study." *Energy Policy* 133 (2019): 110895.
https://doi.org/10.1016/j.enpol.2019.110895