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Investigation on the Performance and Emissions of Ethanol vs. Gasoline on Small Spark Ignition Engine

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Abstract

This research aims to study performance and pollution emissions on the SI generator engine. The effects of loads and speed, loads was changed 1000 to 2500 watts, engine speed was changed from 2000 to 3000 RPM, in addition changed the size main jet according to the type of fuels, to study effect on performance and emission of hydrous (6 % water content in ethanol by volume), anhydrous ethanol fuel comparable gasoline fuels. The results show that the use of ethanol fuels increased the relative air/fuel ratio (Lambda), exhaust temperature, specific fuel consumption (SFC), fuel conversion efficiency (η_f), carbon dioxide (CO2), nitrogen oxides (NOx) while carbon monoxide (CO) and hydrocarbons (HC) emissions decreased. In addition, the brake mean effective pressure (BMEP) promising direction.

***Keywords**:* hydrous ethanol, anhydrous ethanol, performance, emission, spark ignition.

1. Introduction

The increasing of global energy demand and stringent pollution regulations has promoted research on alternative fuels. In Thailand, ethanol can be produced from many sources of national agriculture products as renewable fuel. In addition, the raw materials for ethanol production, cassava and sugarcane, are also the main economic crops in Thailand.

The combustion of ethanol emits greenhouse gas to the atmosphere as same as gasoline. However, in theoretical the net emission of carbon dioxide is zero while gasoline combustion is 100% emitted to the atmosphere. Due to the ethanol is produced from biomass, as plants. The growths of plant pull out of the atmosphere to be a carbon by photosynthesis. So the carbon dioxide emitted from bio-combustion and the carbon dioxide absorption of the bio-plants is balance, the increasing of greenhouse gas in the atmosphere can assume to be zero.

Despite the lower heating value of ethanol compared to that of gasoline, ethanol release a little more heat than gasoline under the same equivalence ratio. Moreover, a high octane number allows higher compression ratio; thus, an engine fueled with ethanol can have higher power output and better thermal efficiency. The use of ethanol in gasoline conventional engines is to reduce regulated pollutant emissions produced by internal combustion engines, as well as to reduce the greenhouse effect impact of transportation.

Needless to say, NOx and HC emissions are prejudicial effects on the environment and human health.

Finally, the objectives of this study are to investigate engine performance and pollution a small SI engine in order to use gasoline, hydrous and anhydrous ethanol fuel. These fuels are tested on single cylinder spark ignition, 4 strokes, generator engine.

2. Materials and methods

The generator engine carburetor type, controlled by carburetor and governor working together to control the speed of the engine as well as the mixture of air and fuel. The carburetor mixes the fuel and air from the inlet on the way to the engine manifold, or through the venturi are made available higher speed and a vacuum to suck out the oil pipeline jet float is the amount of fuel, main jet controls the size of the circuit in the carburetor, while the governor controls the speed of the engine as the load on the engine changes.

This work objective was the comparative performance and emission on the generator engine for use anhydrous and hydrous as a fuels base on gasoline, by adjusting engine speed (1000, 1500, 2000 and 2500 RPM) with engine load were variable by using the electric lamp from 1000 watts to 2500 watts. Engine revolution could be measured by a tachometer. High precision weight loss meter was used to measure the fuel consumption. HC, CO, CO2 and NOx were also measured by the exhaust gas analyzer of the MAHA emission tester. Air fuel ratio could be measured by using oxygen sensor in the exhaust manifold, temperature intake and exhaust were also measured by digital thermocouples.

The first section of research to find the stoichiometric combustion of fuels of the main jet size of the carburetor when use hydrous and anhydrous ethanol as a fuel instead of gasoline. The main jet size can be calculated from the theoretical equivalent ratio of each fuel, gasoline used No. 80, anhydrous ethanol is No. 101 and hydrous ethanol is No. 102.

Fig. 1 Main jet of carburetor.

2.1 Fuel

Table. 1 Typical physical-chemical characteristics of fuels, [1-4]

Fuel properties	Gasoline	Anhydrous	Hydrous
Formula	$C_{6.97}H_{14.02}$	C_2H_5OH	$C_2H_{6.16}O_{1.08}$
Density (kg/m^3)	750.8	790	810
LHV (MJ/kg)	42.6	26.7	25.0
$(A/F)_S$ ratio	14.7	9.0	8.7
Carbon mass (%)	85-88	52.2	50.59
Hydrogen mass (%)	12-15	13.1	12.98
Oxygen mass (%.)	0	34.7	36.42
Self-ignition (^oC)	257	423	420
Heat of vaporization (kJ/kg)	349	923	992.1
Octane number			
Research	95	108.6	106
Motor	85	89.7	87
Vapor pressure (kPa)	48-103	15.9	15.4

Ethanol has higher evaporation heat, higher octane number and the low evaporation pressure compared with gasoline, and contains 34.7% oxygen by weight. There are many points on engine performance when ethanol is used as fuel. If the amount of ethanol increases in blended fuel, the heating value decreases. But on the other hand, increase of ethanol amount in blended fuels to decrease of air–fuel ratio. [5].

2.2 Engine

Generator engine (Mitsuki EC 3900AE+DC), was chosen for this project.

Table. 2 Electric generator engines

Engine Type	Air-cooled, Single cylinder, 4-stroke OHV
Bore x Stroke	68 x 54 mm
Displacement	196 cm^3
Compression Ratio	8.5:1
Carburetor Type	Butterfly
Max output	3000 W
Rated output	2800 W
Fuel Tank Capacity	600 cm^3
Lubricating Oil Life Time	100 hrs. or 6 months

2.3 Experiment and procedure

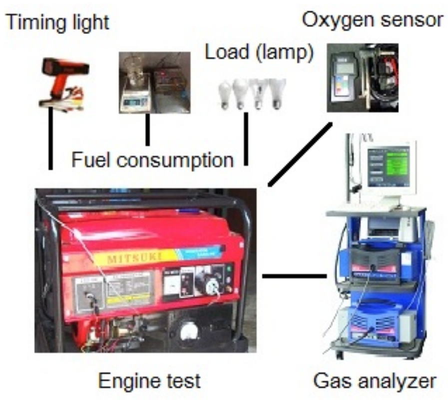

Fig. 2 The schematic diagrams of experimental setup

The engine operating conditions load that were 1000, 1500, 2000 and 2500 watts, each load to be adjusted engine speed for a test each fuel. Such as for load 1000 watt, were adjusted engine speed are 2000, 2500 and 3000 RPM, can replace by letters 1000a 1000b and 1000c respectively.

The equations used to determine the performance of the engine can be obtained as torque, brake mean effective pressure, specific fuel consumption and fuel conversion efficiency [6]. The Torque (*T*) calculated from power output of generator engine.

$$T = \frac{P}{2\pi N} \quad (1)$$

Where *P* is electric power output and *N* is speed engine. Brake mean effective pressure *(bmep)* is a measure of the power produced per cycle as a function of engine size.

$$bmep = \frac{P n_R \times 10^3}{V_d N} \quad (2)$$

Where V_d is the piston displacement volume per cycle and n_R is the number of crank revolutions for each power stroke per cylinder (n_R = 2 for four-stroke cycles). The fuel flow rate per unit power output or specific fuel consumption (*bsfc*).

$$bsfc = \frac{\dot{m}_f}{P} \quad (3)$$

Where $\dot{m}_f$ is the mass flow rate of fuel. The measure of an engine's efficiency, which will be called the fuel conversion efficiency (η_f)

$$\eta_f = \frac{1}{sfc\, Q_{LHV}} \quad (4)$$

Where Q_{LHV} is the fuel lower heating value.

The research review [7] found that main jet test of anhydrous and hydrous with various loads from 0 watts to 3000 watts, there are two main jet size can be used for all of load conditions in practical, No. 115 and 120, should be considered for fuel economy optimization so that selected main jet is No.115 for tested this research.

3. Results and discussion

Test results are presented in graphs, the condition tested each fuels and engine load each revolution. The relative air/fuel ratio (lambda) will change according engine load, the mainly generator engine is fuel-lean mixture and however rich mixture will occur for gasoline fuel more than ethanol fuels. When the lambda value is not controlled, the effect magnitude of the change in emissions is strong. [8]. Fig. 3 show the result of lambda according operating conditions, ethanol fuels gets lean mixture and gasoline rather rich mixture. Fig. 4 show variation of intake and exhaust temperature, air intake all three fuels are similar, and exhaust temperature of ethanol fuels slightly higher gasoline fuel. Fig. 5 shows the specific fuel consumption, ethanol fuels higher gasoline, due to ethanol fuels are lean mixture. Fig. 6 show brake mean effective pressures of the three fuels are tending in direction increased, due to governor operation in order to electrically power output stable. Fig. 7 show the fuel conversion efficiency generally increased with the use of ethanol content. It was observed that rich mixture of gasoline fuel, however anhydrous fuel highest at 2500W 2000rpm and lowest at 2500W 3000rpm. Fig. 8 show carbon monoxide of ethanol fuels lower than gasoline and anhydrous ethanol lowest value. Fig. 9 shows increase carbon dioxide of ethanol fuels. Fig. 10 show the hydrocarbon of hydrous ethanol slightly higher at low revolve and gasoline has higher than when compares every load almost all. Fig. 11 shows the increase NOx of ethanol fuels, particularly at high load (from above 2000 watts).

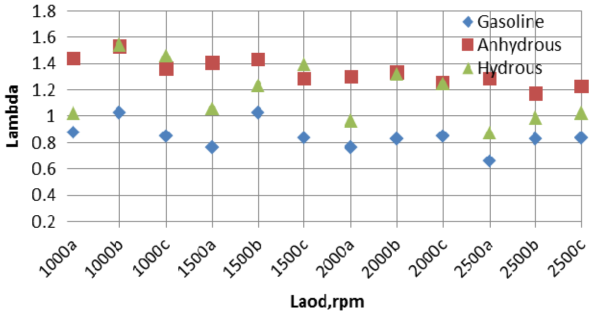

Fig. 3 Variations of lambda

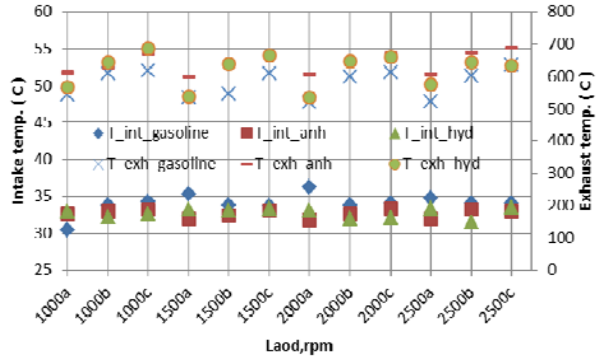

Fig. 4 Variations of air temperature

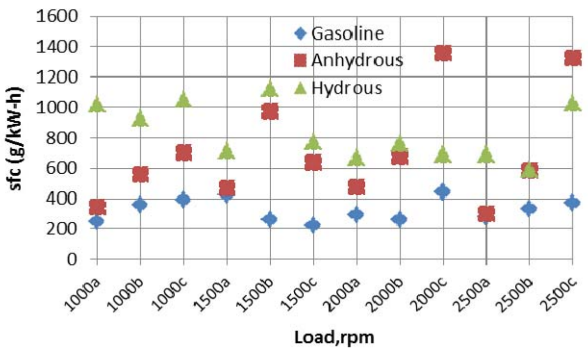

Fig. 5 Variations the specific fuel consumption

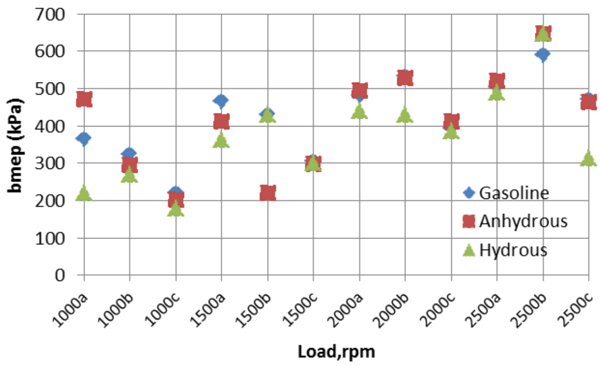

Fig. 6 Variations of brake mean effective pressure

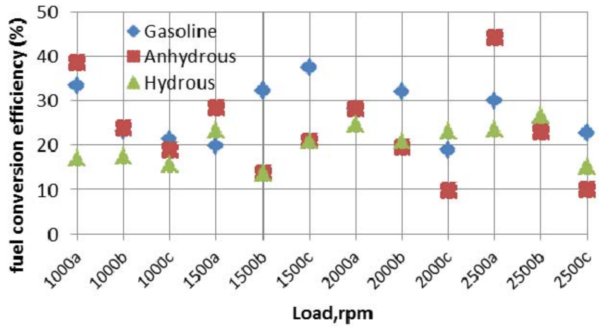

Fig. 7 Variations of the fuel conversion efficiency

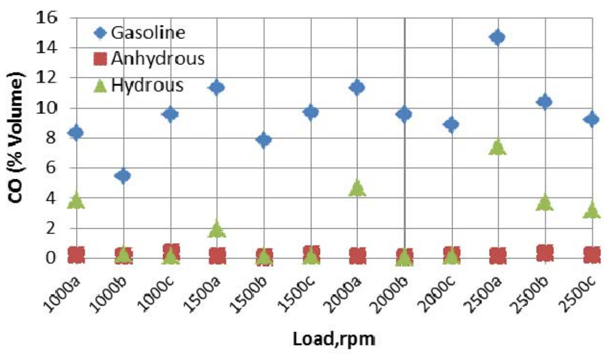

Fig. 8 Variations of carbon monoxide

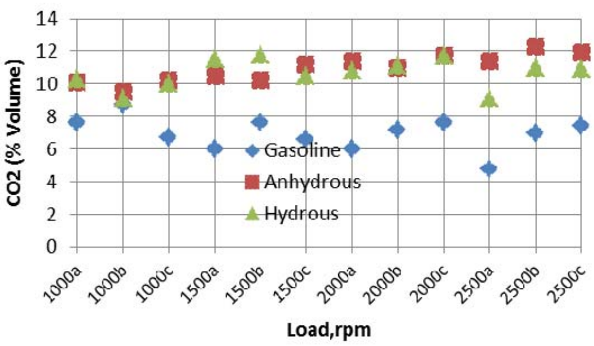

Fig. 9 Variations of carbon dioxide

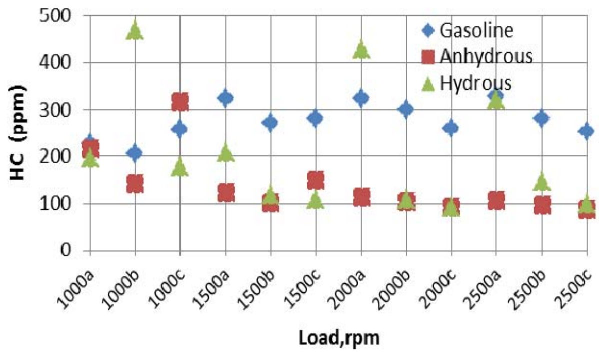

Fig. 10 Variations of hydrocarbon

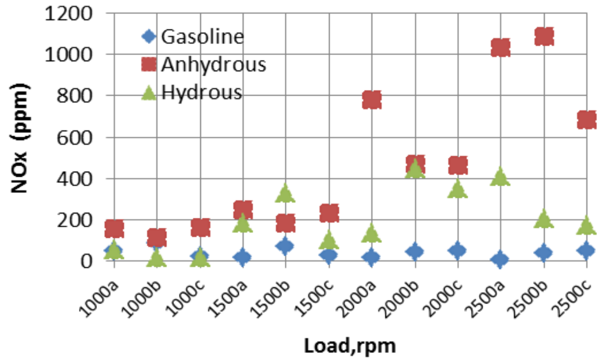

Fig. 11 Variations of oxides of nitrogen

4. Conclusion

The result shows that the performance and exhaust emissions of the electric generator engine when used anhydrous and hydrous ethanol comparison gasoline at different load, engine speeds. In addition changed the size main jet according to the type of fuels. The following results can be obtained from the current study. In all fuels, the engine speed and loads increase are main operating variables, however the relative air/fuel ratio (lambda) value is not controlled.

Intake temperature decreases with the presence of water but does not decrease further with his content [9]. Hydrous ethanol with high water content (up to 40% by volume) can be used in a small SI engine generator, especially in remote and rural areas where ethanol can be produced locally. [10]. The main conclusions for use ethanol fuels (hydrous and anhydrous) compared gasoline fuels can be summarized as follows:

- Lambda value according operating conditions, ethanol fuels get lean mixture and gasoline rather rich mixture due to the lambda value is not controlled.
- The exhaust temperature of ethanol higher than gasoline due to combustion more complete, that anhydrous maximum at 2500 watts 3000 RPM (689 ^{o}C).
- The specific fuel consumption (sfc) of ethanol fuels higher than gasoline due to lean mixture moreover ethanol lower heating value and anhydrous fuel maximum at 2000 watts 3000 RPM (1357.4 g/kWh).
- The brake mean effective pressure (bmep), there are promising direction, due to governor operation in order to electrically power output stable and ethanol fuels are maximum at 2000 watts 2500 RPM (646.2 kPa) better than gasoline up to 10.73 %.
- The fuel conversion efficiency of anhydrous has a maximum value at 2000 watts 2000 RPM higher than gasoline up to 71.87 %.
- The use ethanol fuels were decreases carbon monoxide (CO), hydrocarbon (HC) due to the lower carbon content of the ethanol fuels while carbon dioxide (CO2), nitrogen oxides (NOx) emissions increases, compared with gasoline, this relationship engine operating conditions load increase.

Since oxygenated fuel has a strong effect on particle emissions of combustion, using ethanol instead of gasoline may reduce emissions and pollutions from internal combustion engine. In the case of anhydrous ethanol is very expensive, anhydrous ethanol is also one of a good option for small SI engine.

5. Acknowledgement

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7. References

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