Performance and Emission of a Small Engine Operated with LPG and E20 Fuels

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Abstract

The engine performance and exhaust emissions of a small engine were experimentally investigated. The engine with displacement of 197 cm^3 (12 in^3) was minor modified and operated with gasoline, liquefied petroleum gas (LPG) and ethanol fuel mixture blending 20% ethanol and 80% gasoline (E20). The engine testing was done over a wide range of engine speed. Engine power, fuel consumption and exhaust emissions of the engine using gasoline, LPG, and E20 were measured and compared. The experimental results showed that small engine operated with LPG had lowest power and torque while engine operated with gasoline and E20 had comparable power. However, using LPG on small engine had lowest fuel consumption and carbon monoxide (CO) emission compared to that of using gasoline and E20. Engine operated with E20 provided least hydrocarbon (HC) concentration than that of LPG and gasoline. Considering the results of engine power and exhaust emissions, using gasoline on small engine gave the best output engine power while using LPG and E20 had lowest CO emission and lowest HC concentration, respectively.

Keywords*:* small engine, performance, emission, LPG, E20, fuel consumption

1. Introduction

The fuel limitation and environmental pollutions are important for human kind to find alternative fuels and sustainable energy. Fossil fuel is major used to provide energy for transportation and industrial sectors. However, demanding of fuel is rising and unlimited which completely opposites with production ability and limited crude oil. Accordingly, an increasing of fuel price is continuing crisis and impact. Many automobiles were modified to be used with various alternative fuels as other choices instead of gasoline and diesel. Alternative fuel such as natural gas, hydrogen, biomass, vegetable oil and alcohol fuel are sought as an option for automobile.

LPG and E20 (the blend of 20 vol % ethanol and unleaded gasoline) are attractive fuel choices for many commercial vehicles and industries because of cheap cost, reasonable octane number, and also low emissions than conventional gasoline.

There are many intensively simulation and test in the internal combustion engines. Bayraktar and Durgun [1] simulated performances and exhaust emissions of an automotive engine using gasoline and LPG. LPG reduces the engine volumetric efficiency and thus decreases power and increases specific fuel consumption. However, LPG has advantage on lower exhaust emission such as CO and NO_x than gasoline. Murillo and et al [2] showed the experiment of LPG in spark-ignition outboard engines. Their results indicated that using LPG, emissions were lower than using gasoline which would reduce pollutant from marine engines. Lai et al. [3] presented emissions of LPG from motor vehicles in downtown Guangzhou. They used LPG alkanes such as propane, iso-butane, and n-butane. The emissions of the LPG fleet were likely to increase more than those of the gasoline fleet during the morning and evening rush hour and noontime break as well. In addition, Lee S. et al [4] performed experimental study on performance and emission characteristics of an SI engine operated with di-methyl ether (DME) mixed with LPG. The results they obtained showed that knocking was significantly increased with DME due to the high cetane number of DME. The output engine power of using 10% DME was comparable to that of pure LPG. Exhaust emissions such as HC and NO_x were slightly increased when utilizing blended fuel at low engine speeds. Using blended fuel, however, the engine power output was decreased and break specific fuel consumption (BSFC) was extremely deteriorated because the energy content of DME is much lower that that of LPG.

Yucesu et al., [5] showed using ethanol fuel blend in SI engine gave a higher engine torque than that of gasoline fuel. The air-fuel ratio of about 0.9 provided the maximum engine torque. In addition, the ethanol-gasoline blends (E0, E10, E20, E40 and E60) on engine emissions and performance were also investigated by Yucesu et al., [6]. Moreover, Najafi et al., [7] presented the agreement of experimental data with numerical results by using artificial neural network (ANN) on 4-cylinder engine.

Although, many research works have been conducted but mostly adapted with high power engines while small gasoline engines are widely used as prime movers. Accordingly, this research focused on a small engine. The small gasoline engine has been modified and developed for running with LPG, ethanol-gasoline blend and gasoline. The engine performances and emission has been tested and compared at various engine speeds.

2. Experimental Equipments and Procedures

2.1 Fuel Properties

LPG can be obtained from natural gas and crude oil while ethanol-gasoline blend fuel can be derived from mixture of ethanol and unleaded gasoline. LPG mainly composes of propane and butane. The comparison of gasoline, propane and ethanol properties were given in Table 1. The properties of gasoline (E0) and ethanol-gasoline blend fuels, E10 and E20, are presented as in Table 2. Propane has lower density and stoichiometric fuel-air ratio than gasoline. That means using LPG has the specific fuel consumption and exhaust emissions are lower than that of gasoline. Therefore, LPG is attractive fuel choice for spark ignition engines.

Table. 1 Some properties of gasoline and ethanol (Yucesu et al., [5])

Properties	Gasoline	Propane	Ethanol
Chemical formula	C_7H_{17}	C_3H_8	C_2H_5OH
Molecular weight g/mol	100-105	44.10	46
Density at 15 °C, kg/m^3	507	690	789
Oxygen (mass%)	0-4	-	34.7
Net lower heating value(MJ/kg)	43.5	46.40	27
Latent heat (kJ/L)	223.2	221	725.4
Stoichiometric air/fuel ratio	14.7	15.5	9
Vapor pressure at 23.5 °C	60-90	42	17
Motor Octane Number (MON)	82-92	95.4	92
Research Octane Number(RON)	91-100	100	111

Table 2 Properties of different ethanol-gasoline blends

Property items	Test fuels		
	E0	E10	E20
Stoichiometric air/fuel ratio (theoretical)	14.60	14.39	14.11
Octane number(research)	85.3	92.3	99.4
Distillation range(°C)			
IBP	35.8	38.9	40.8
10 vol%	58.6	53.1	55.4
50 vol%	93.3	71.9	71.6
90 vol%	146.0	143.9	142.1
End point	176.7	175.1	176.6

2.2 Engine specifications

In the experimental investigation, a single cylinder four stroke side valve with carburetor was tested. Specifications of the engine are given in Table 3.

Table 3 Test engine specifications

Item	Specification
Engine Type	4 stroke side valve
Engine Displacement	197 cc
Engine Power	5.5 HP
Cooling	Air
Cylinders	Side valve single
Bore* Stroke	67 x 56 mm
Compression	6.5 : 1
Maximum Power	3.7 kW(5psi @ 3600 rpm
Recommended Power	3.3 kW(4.5 psi (@ 3600 rpm
Maximum Torque:	10.4 Nm)1.06kg-m(@ 2500 rpm
Starting :	Recoil
Air Cleaner:	Semi dry
Shaft:	3/4 keyed
Fuel Capacity:	4.3 liter
Oil Capacity	0.7 liter
Fuel Consumption	390 g/kW-hr
Rating:	Domestic
Dimensions(L x W x H)	327x 375 x438 mm
Weigh (Dry)	15 kg

2.2. Equipment and set up

Fig. 1 showed the schematic of the experimental set up. In the fuel supply system, LPG pressure was reduced and controlled by pressure regulator and pressure gage as pressure indicator. Fig. 2 shows the experimental set up for testing of E20 and gasoline. The engine is connected to dynamometer with drive shaft for measuring torque and power. Fuel consumption was measured in sensitivity of 0.01 g and for time measurement. Air fuel ratio and exhaust emissions were measured using gas analyzer which directly attached to the muffler.

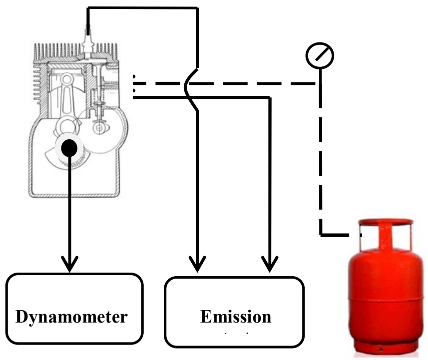

Fig. 1 Schematic of the experimental set up

Fig. 2 Experimental Setup

2.3 Testing procedure

The effect of LPG, E20 and gasoline on engine performance and emissions has been investigated and compared. The tests were performed at engine speed variation from 2000 to 4000 rpm, and full open intake ports. Torque and power were measured at 3000, 3600, and 4000 rpm. Exhaust emissions were obtained by gas analyzer at 2000, 2500, 3000, 3500, and 4000 rpm. Fuel consumption was observed at different engine speed. Fuel consumption of using gasoline was reported in liter per hour while that of using LPG was recorded in kilogram per hour.

Since the engine could not run smoothly at engine speed of 3000 rpm with using E20, the experiment results, therefore, were obtained separately between LPG and E20.

3. Experimental Results and Discussions

3.1 Engine performance

The relationship of net power and torque at different engine speed for LPG and gasoline and for E20 and gasoline were presented in Figs. 3 -6.

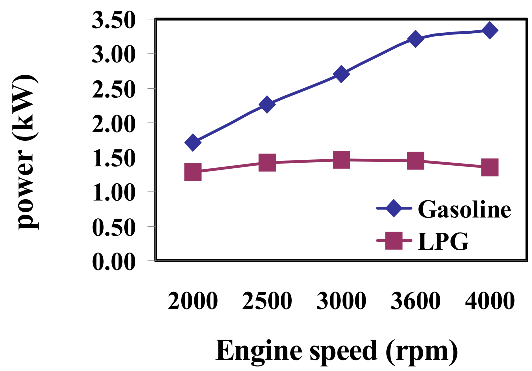

Fig. 3 Net output power at different engine speeds for LPG and gasoline

Fig. 3 presents the power at engine speeds (2000-4000 rpm). Net power was higher with the increasing of the engine speed for gasoline while using LPG could reach optimum power at 3000 rpm.

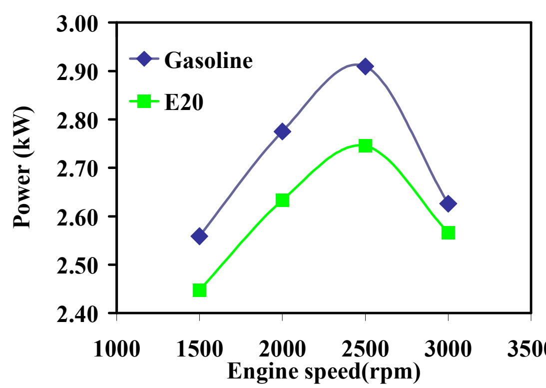

Fig. 4 Net output power at different engine speeds for gasoline and E20

Fig. 4 shows the effect of gasoline and ethanol-gasoline blended fuel, E20, on engine power. The maximum power could be achieved at 2500 rpm engine speed.

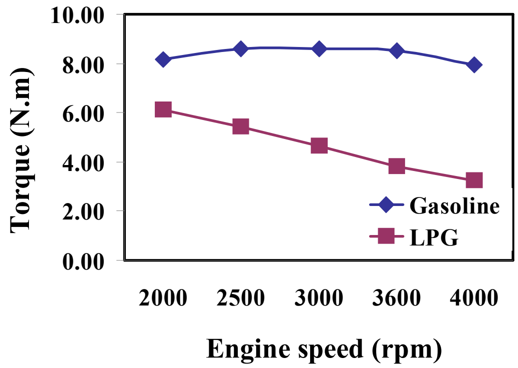

Fig. 5 Relationship of output torque at different engine speeds for LPG and gasoline

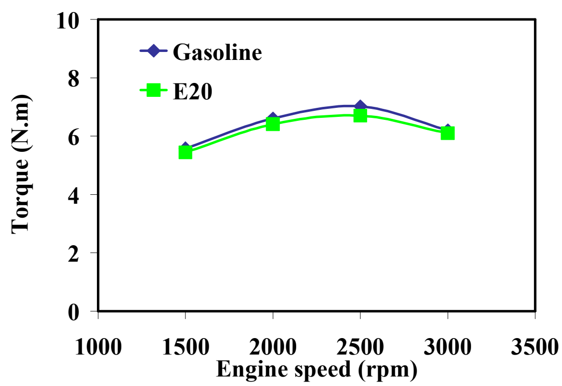

Fig. 6 Relationship of output torque at different engine speeds for E20 and gasoline

Fig. 5 shows influence of LPG and gasoline on engine torque. Power and torque produced from engine with using LPG is obviously lower than that with using gasoline. Fig. 6, however, illustrates comparable torque produced from the engine when using E20 or gasoline as fuel. The ethanol content up to 20% is not significantly reducing output torque on the small engine.

3.2 Fuel consumptions

Fig. 7 presents the relationship between engine speed and fuel consumption for gasoline. The fuel consumption increased with the increasing of engine speed. For LPG, fuel consumption at the engine speed variation from 2000 to 4000 rpm was varied 0.55 to 0.77 kg/hr, respectively.

Fig. 8 presents the relationship between engine speed and fuel consumption for E20 and gasoline at the engine speed variation from 1500 to 3000 rpm was varied 0.23 to 0.36 kg/hr, respectively. The fuel consumption increased with the increasing of ethanol percentage and engine speed.

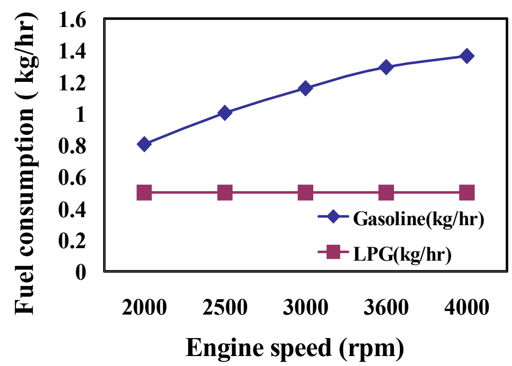

Fig. 7 Fuel consumption of gasoline and LPG at different engine speed

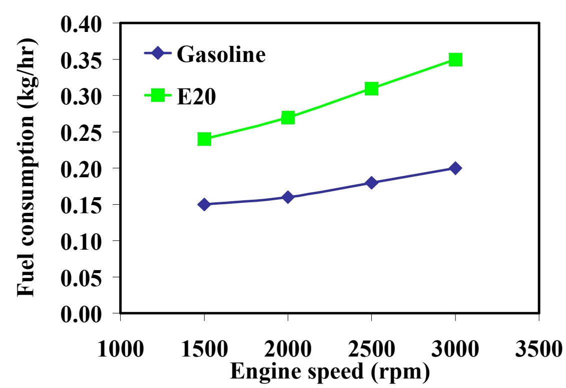

Fig. 8 Fuel consumption of gasoline and E20 at different engine speeds

3.3 Engine emissions

Fig. 9 shows the concentration of CO emission for engine speed variation on the small engine. As engine speed increased, the CO emission increased, especially, for gasoline. The CO concentrations at engine speed above 3000 rpm for gasoline were extremely increased which also agree with that of E20 and gasoline in Fig.10. The CO concentration from using LPG was significantly lower than that of gasoline. The lower CO indicated that the combustion was turned to be completed.

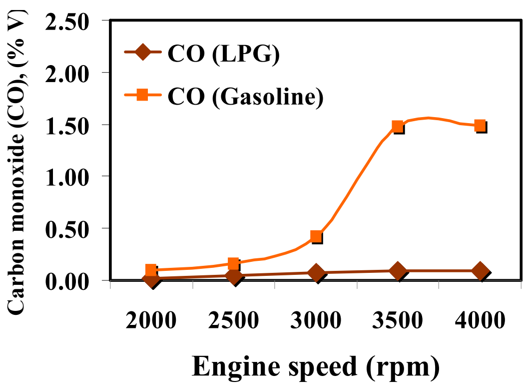

Fig. 9 Relationship of CO and engine speed for LPG and gasoline

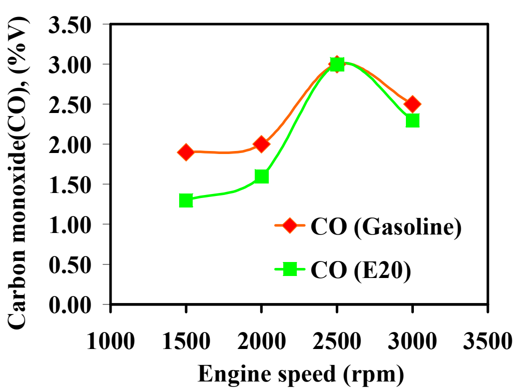

Fig. 10 Relationship of carbon monoxide (CO) and engine speed of gasoline and E20.

Fig. 10 shows the concentration of CO emission for engine speed variation on the small engine using E20 and gasoline. The ethanol content decreased the CO indicating that the combustion was turned to be completed. The CO concentrations at engine speed at 2500 rpm of E20 and gasoline were about the same. It could be seen that E20 or gasoline with ethanol content significantly impacted on CO emission at lower engine speed. LPG provided lowest CO comparing with E20 and gasoline.

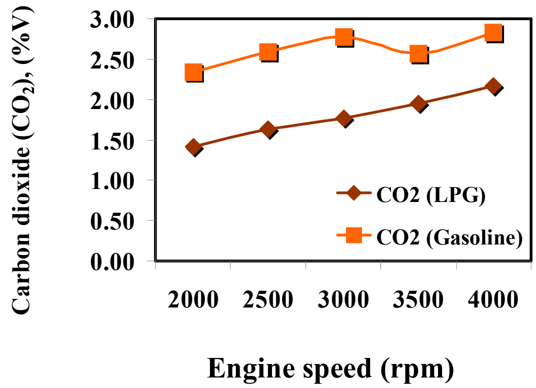

Fig. 11 Relationship of CO_2 and engine speed for LPG and Gasoline

The relationship of CO_2 emissions and engine speed for LPG and gasoline were shown as in Fig. 11. The CO_2 emission indicated potential of complete combustion. The CO_2 concentration increased as the engine speed increased. The CO_2 exhaust at 3000 rpm for gasoline fuel was 2.77 % volume while the CO_2 concentration of LPG at the same speed was 1.77 % volume. The CO_2 concentration at 3000 rpm using LPG was decreased by 36.10% in comparison to gasoline. The CO_2 emission was increased due to the increasing of fuel consumption at higher engine speed.

The relationship of CO_2 emissions and engine speed with E20 and gasoline were shown as in Fig. 12. The CO_2 concentration increased when utilizing E20 as fuel. The CO_2 exhaust at 2500 rpm for gasoline fuel was 1.33(%V) while the CO_2 concentration of E20 at the same speed was 1.93 (%V). The CO_2 concentration at 2500 rpm using E20 was increased by 45.11%, respectively in comparison to gasoline. The ethanol blended fuel gave lean combustion, increasing of CO_2 emission because the combustion was improved.

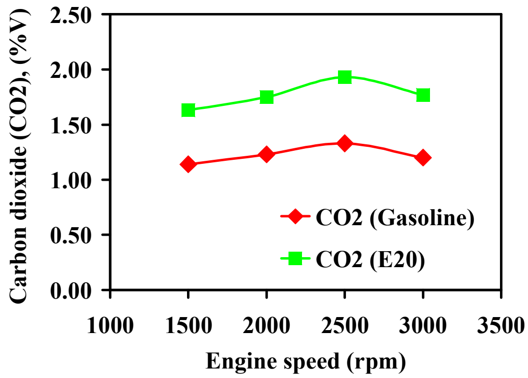

Fig. 12 Relationship of carbon dioxide (CO_2) and engine speed of gasoline and E20.

HC emissions show incomplete combustion and also indicate unburned fuel. HC emissions with varying engine speed for LPG and gasoline were illustrated in Fig. 13.

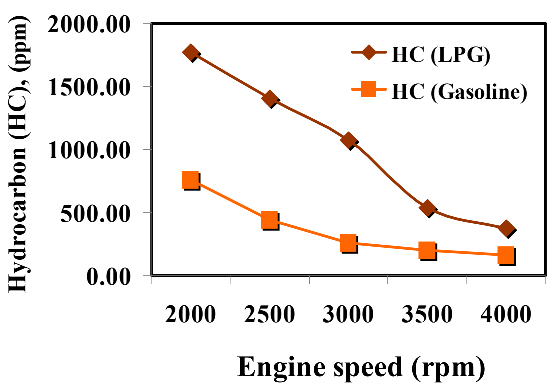

Fig. 13 Relationship of HC and engine speed for LPG and

The HC exhaust at 3000 rpm for gasoline was 257 ppm, while the HC concentration of LPG at this speed was 1070 ppm. The HC concentration at 3000 rpm using LPG was increased by 300 % in comparison to using gasoline. HC concentration from using LPG was obviously higher than that from gasoline. The CO_2 emission of using LPG was lower than that of gasoline because unburned LPG was converted to be the HC emission. Lacking of air for combustion resulted in thick mixture and introduced HC instead of CO_2. For these reasons, engine should be modified to achieve complete combustion.

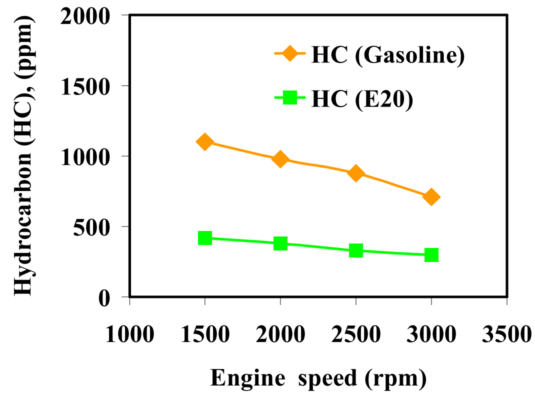

Fig. 14 Hydrocarbon (HC) at different engine speeds of gasoline and E20.

Fig.14 illustrates HC emissions with varying engine speed for E20 and gasoline. The HC exhaust at 2500 rpm for gasoline was 878 ppm, while the HC concentration of E20 at this speed was 330 ppm. The HC concentration at 2500 rpm using E20 was decreased by 62.41 %, respectively in comparison to gasoline. The results show that ethanol can significantly reduce HC emissions.

4. Conclusions

This study presents an experimental investigation of LPG, E20 and gasoline on the small engine characteristic and performance. Power, torque, fuel consumption and exhaust emissions of the engine compared between LPG and gasoline and between E20 and gasoline. The experimental results can be summarized as the following:

1.Power and torque produced from engine with using LPG is obviously lower than that with using gasoline.

2. The small engine operated with E20 had lower torque and higher fuel consumption than using gasoline.

3.The fuel consumption increased with the increasing of engine speed.

4. The CO concentration from using LPG was significantly lowest compared to E20 and gasoline. The engine emissions of E20 at 2500 rpm with an engine displacement of 197 cm^3 (12 in^3) had lower CO and HC but higher CO_2. The CO_2 concentration at 2500 rpm using E20 was increased 45.11% in comparison to gasoline.

5.The CO_2 emission was increased due to the increasing of fuel consumption at higher engine speed.

6.The CO_2 concentration at 3000 rpm using LPG was decreased by 36.10% in comparison to gasoline. The CO_2 emission of using LPG was lower than that of gasoline because unburned LPG was converted to be the HC emission.

7. HC concentration from using LPG was obviously higher than that from gasoline.

8. The HC concentration at 2500 rpm using E20 was decreased by 62.41 % in comparison to gasoline.

9. Lacking of air for combustion resulted in thick mixture and introduced HC instead of CO_2. For these reasons, engine should be modified to achieve complete combustion.

5. References

[1] Bayraktar, H. and Durgun, O., (2005). Investigating the effect of LPG on spark ignition engine combustion and performance, *Journal of Energy Conversion and Management*, vol. 46, pp. 2317-2333.

[2] Murillo, S., Miguez, J.L., Porteiro, J., Lopez Gonzalez, L.M., Granada, E., and Moran J.C. (2005). LPG: Pollutant emission and performance enhancement foe spark-ignition four strokes outboard engines. *Journal of Applied Thermal Engineering*, pp. 1882-1893.

[3] Lai, C. H., Chang, C. C., Wang, C. H., Shao, M., Zhang, Y. and Wang, J. L. (2009). Emissions of liquefied petroleum gas (LPG) from motor vehicles. *Atmospheric Environment*, (43) pp. 1456-1463.

[4] Lee, S., Oh, S., and Choi, Y. (2009). Performance and emission characteristics of an SI engine operated with DME blended LPG fuel. Fuel, vol. 88, pp. 1009-1015.

[5] Yücesu, H. S., Topgül, T., Çinar, C.,and Okur, M. (2006). Effect of ethanol–gasoline blends onengine performance and exhaust emissions in different compression ratios. *Applied Thermal Engineering,* vol. 26 (17–18), pp. 2272–2278.

[6] Yücesu, H. S., Sozen, A., Topgül, T., and Arcaklioglu, E. (2007). Comparative study of mathematical and experimental analysis of spark ignition engine performance used ethanol–gasoline blend fuel. *Applied Thermal Engineering*, vol. 27, pp. 358–368.

[7] Najafi, G., Ghobadian, B., Tavakoli, T., Buttsworth, D.R., Yusaf, T.F., and Faizollahnejad, M. (2009). Performance and exhaust emissions of a gasoline engine with ethanol blended gasoline fuels using artificial neural network. *Applied Energy,* vol. 86, pp. 630–639.