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Research Article

A Study on Engine Performance and Emission Characteristics of Gasoline Spark Ignition Engine with Methanol and Ethanol Addition

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Abstract Spark ignition engines for gasoline were mixed with ethanol and methanol fuel, and various performance characteristics and exhaust gas characteristics were compared and analyzed. Regarding the engine speed change, the torque, the brake mean effective pressure (BMEP), and the engine output are the largest gasoline, and although there is a slight difference, the torque and engine output tend to be reduced when the amount of mixture of ethanol and methanol is increased. The emission of CO, HC, and NOx decreased rapidly as the ethanol and methanol contents increased. Especially, when ethanol and methanol were added to gasoline at 1,400 rpm, exhaust gas was optimal. Especially, the effect of ethanol addition was greater than that of methanol.

Keywords Gasoline, Ethanol, Methanol, Torque, BMEP (Brake Mean Effective Pressure), BSFC (Brake Specific Fuel Consumption), Brake Thermal Efficiency, CO, HC, NOx

Introduction

At present, the problem of air pollution is becoming a serious issue all over the world. Due to strict exhaust gas regulations, much research has been conducted on the reduction of exhaust gas of automobiles. At this point, consider what is the best way. Fuel such as hydrogen, natural gas or alcohol can be used [1-3].

It is true that research on alcohol fuels among various fuels has been done for a long time. Biofuels are under study due to the exhaustion of fossil fuels and the atmospheric environment. Alcohol fuels such as methanol and ethanol play an important role in the category of biofuels [4-6].

Methanol can be produced from coal, biomass as well as natural gas. In addition, it is known that there is sufficient economic value in terms of price. Ethanol can be obtained from sugarcane and starch from fermentation. Alcohol fuels are emerging as renewable fuels to replace fossil fuels [7-9].

The ability to obtain methanol and ethanol from biomass and renewable fuels is a truly attractive result. In addition, studies on the mixing of gasoline and alcohol fuel have been actively conducted. Gasoline fuels that already contain HC are not particularly clean fuels. However, since the pure alcohol has a structure containing oxygen, it is considered to perform more homogeneous combustion than gasoline fuel. Gasoline, especially unleaded gasoline, is mixed with ethanol and methanol, which is known to significantly reduce exhaust gas emissions from gasoline fuels [10,11].

In this study, the performance evaluation and the exhaust gas are evaluated through an experimental study on the mixture of gasoline fuel, gasoline and ethanol fuel, gasoline and methanol. The purpose of this study is to diagnose the possibility of spark ignition engine for the homogeneous charge compression ignition engine as an alcohol mixture fuel based on this study.

Experimental Apparatus and Test Methods

To understand the performance and emissions characteristics of gasoline and alcohol fuels in the spark engine, a spark ignition was used. In this experiment, a single cylinder, spark ignition engine was modified into a blended fuels engine.

Table 1 shows the engine specifications used in the study.

Fig. 1 shows a schematic diagram of the experimental apparatus. The engine used in this study was a gasoline engine with four cycles and four cylinders. As a water-cooled engine, an automotive engine with a compression ratio of 8.0 was used. Fuel was obtained by mixing methanol and ethanol with pure gasoline. The fuel supply was MPI (Multi Point Injection). The performance was tested by connecting the crank shaft to a DC dynamometer. An engine control system (IC 5460, INTELLIGENT CONTROLS, INC.) was used to control the fuel injection timing and spark timing for gasoline fuel and alcohol fuels. An air-fuel ratio measurement system (UEGO Sensor, HORIBA 110) was used to measure the air-fuel ratio. The air-fuel ratios were the experimental operating variables at a part load. The engine speed changed from 1000 rpm to 1800 rpm. The cooling water temperature is fixed at 80°C. A piezo-electric pressure transducer, Kistler 6061B, was mounted in the cylinder head to measure the cylinder pressure.

A DC dynamometer was used to control and measure the load applied to the engine, and thermocouples were inserted to measure the temperature of each part of the intake pipe, exhaust pipe, engine oil, etc. In order to obtain the pressure curve, the pressure value was sampled and the pressure sensor was connected to the combustion analyzer using a spark plug integral pressure sensor. The gasoline or alcohol injector is fixed to the intake manifold about 10mm ahead of the intake valve. Mixing fuel is injected during the induction process, and its quantity is controlled. The average cylinder pressure diagram of the 100 consecutive cycles was used to evaluate the stability at the rpm.

For data measurement, the crank angle was measured using a crank angle encoder. The engine speed was set at 1,000 rpm, 1,200 rpm, 1,400 rpm, 1,600 rpm, 1,800 rpm. And ignition timing was performed at MBT (Minimum spark advance for the Best Torque). In order to make an accurate judgment of the experimental results, the catalyst was removed and the exhaust gases (CO, HC, NOx) were measured.

Table 2 shows the properties of gasoline, ethanol, methanol blended fuels. A list of fuel properties that compares gasoline, ethanol and methanol are given in Table 2. Table 2 shows the fuel used. E05 means 5% of ethanol in gasoline 95. E10 means 90% of gasoline, 10% of ethanol and E15 means 85% of gasoline and 15% of ethanol. Likewise, M05 means 95% of gasoline and 5% of methanol. M10 means 90% of gasoline, 10% of methanol, and M15 means 85% of gasoline and 15% of methanol. In particular, the low heat value of gasoline is the largest, followed by E05, M05, E10, M10, E15, and M15. And the largest of the value of the research octane number, which is the standard for estimation of engine knocking, is the M15 and the smallest is gasoline.

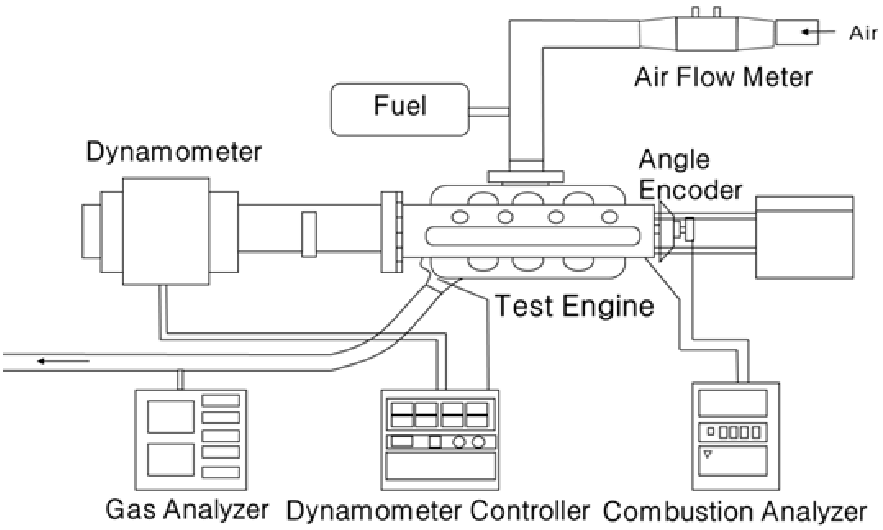

Figure 1: Experimental setup line diagram

Table 1: Engine specifications

Cooling system	Water-Cooled
Displacement	1598 cc
Bore × stoke	76.9 × 86 mm
Compression ratio	8.0
Cylinder number	4
Combustion chamber	Pre-combustion chamber
Nozzle opening pressure	$3 kg/cm^2$

Table 2: Properties of gasoline, ethanol, Methanol blended fuels

Property item	**Gasoline**	**E05**	**E10**	**E15**
	M05	**M10**	**M15**	
Low heat value(MJ/kg)	44.13	43.34	42.45	41.56
	43.31	41.62	39.93	
Vapor pressure (kPa)	35.00	61.99	59.53	57.07
	52.43	57.43	62.00	
Research octane number	84.8	85.75	88.30	90.85
	85.10	88.20	91.30	
Density at 15.5 °C (kg/l)	0.768	0.775	0.776	0.777
	0.768	0.769	0.770	

Experimental Results and Discussion

Figures 2 and 3 show the torque and BMEP versus engine speed for various fuels, respectively. The values of the torque and BMEP are the same as the order of the low calorific value in Table 2. That is, the values of torque and BMEP are the largest for gasoline, showing the magnitude of torque and BMEP values in the order of E05, M05, E10, E15, M10, and M15. And the largest torque and BMEP values are shown near the engine speed of 1,400 rpm.

Fig. 4 shows the engine output with respect to the change in engine speed with respect to fuel change. Since the engine brake power is affected by the torque and the engine speed, the engine output is increasing with respect to the engine speed increase.

Fig. 5 shows the brake specific fuel consumption (BSFC) for changes in engine speed. The fuel consumption rate is generally proportional to the amount of fuel supplied, inversely proportional to the engine output, and also inversely proportional to the torque curve. However, the amount of supplied fuel shows a tendency to be opposite to that of the torque characteristic due to the difference in calorific value of the mixed fuel, which is considered to be the result of the experiment due to the difference in the calorific value even when the supplied fuel amount is constant.

Fig. 6 shows the experimental results showing the thermal efficiency with respect to the change in the engine speed according to the fuels. The thermal efficiency has an inverse relationship with the braking fuel consumption rate and the low calorific value. The thermal efficiency is relatively high near the engine speed of 1,400 rpm.

Fig. 7 shows the change of CO with respect to the engine speed change as a variable of the fuel for the change in the engine speed. CO is relatively low at around 1,400 to 1,500 rpm, E15 is the least CO emission, and M15, E10, M10, E05 and M05 are the next. Pure gasoline fuels are the largest source of CO emissions.

Fig. 8 shows the variation of the HC emissions with respect to the engine speed as the various fuels. HC is relatively low at around 1,600 rpm. However, gasoline is the least emitted at 1,400 rpm and is the highest at 1,600 rpm. Like CO, E15 has the lowest CO emissions, followed by M15, E10, M10, E05, and M05. Gasoline fuels produce the most HC emissions, similar to the trend of CO emissions.

Fig. 9 shows the experimental results of NOx changes with changes in engine speed as fuel variables. NOx is relatively low at around 1,600 rpm and relatively large amounts of NOx are being emitted near 1,400 rpm. It can be seen that gasoline is emitted in a larger amount than alcohol fuel. In addition, NOx emissions emitted the least amount of E15, followed by M15, E10, M10, E05, and M05. Gasoline fuels have the highest NOx emissions compared to other alcohol-blended fuels, similar to trends in CO and HC emissions.

From the above results, in order to understand the torque and the output, particularly the characteristics of the exhaust gas, the CO, HC, and NOx emissions of the exhaust gas were experimentally measured when methanol or ethanol was mixed with gasoline at an engine speed of 1,400 rpm.

Fig. 10 shows the experimental results showing the tendency of CO emission of gasoline and alcohol fuel mixture at engine speed of 1,400 rpm. Generally, the generation of CO occurs due to the lack of oxygen supply. Especially, the region richer than the theoretical mixture ratio is a region where the oxygen supply is insufficient, so that CO generation is increased due to unstable combustion. Compared with the gasoline fuel, the addition of ethanol and methanol shows that the CO decreases dramatically. It can be seen that when ethanol is mixed, the amount of CO emission is relatively small compared to the case of methanol, but the difference is small. In addition, the larger the addition rate of the alcohol content, the smaller the CO emission amount.

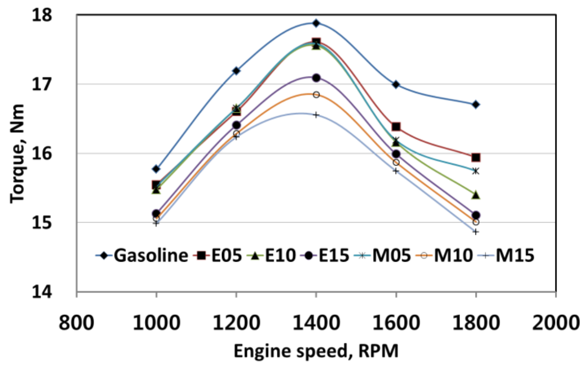

Figure 2: Variation of torque versus engine speed for various fuels

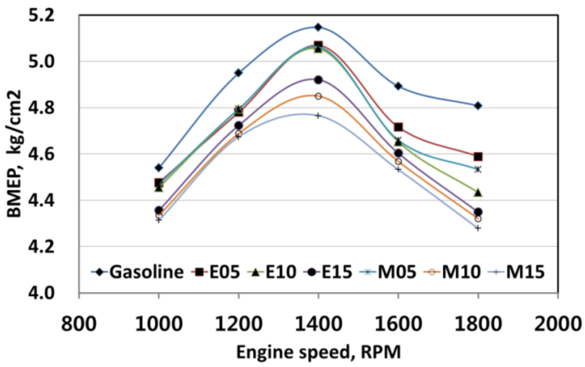

Figure 3: Variation of BMEP versus engine speed for various fuels

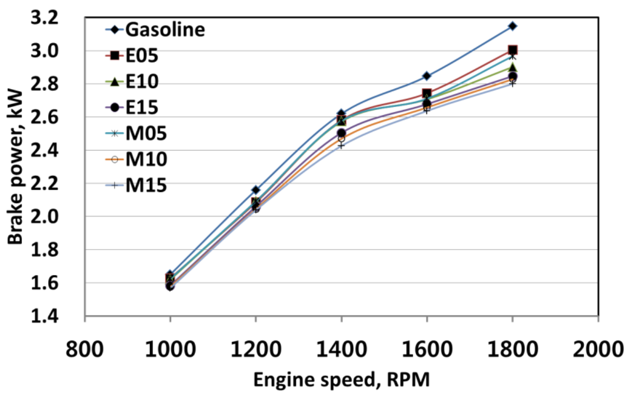

Figure 4: Brake power versus engine speed for various fuels

Fig. 11 is the experimental result showing HC emissions at 1,600 rpm. Generally, HC is an unburnt exhaust gas from incomplete combustion. It can be seen that the generation of HC is remarkably reduced when the alcohol is added compared with the case of operating only with gasoline fuel. It can be seen that when ethanol is mixed, the amount of HC emitted is comparatively lower than that of methanol, but the difference is small. Also, the larger the addition rate of the alcohol content, the less the HC emission amount. Gasoline, based on isooctane, is a hydrocarbon-based paraffin family that already contains HC. However, since alcohol is already oxygenated, it is considered that HC is less generated than gasoline fuel.

Fig. 12 is the experimental result showing NOx emissions for various fuels at 1,600 rpm. Generally, it is known that the higher the combustion temperature, the higher the generation of NOx, and the lower the combustion temperature, the less the generation of NOx. Alcohol fuels have a higher latent heat of vaporization than gasoline, so they have the effect of lowering the combustion temperature. Therefore, if ethanol or methanol is mixed with gasoline, the combustion temperature will be lower than that of gasoline. As with CO and HC, NOx generation is less as the mixing ratio of ethanol and methanol is higher than that of gasoline. It can also be seen that the effect of mixing ethanol with gasoline is greater. Also, it can be seen that the larger the addition rate of the alcohol content, the smaller the NOx emission amount.

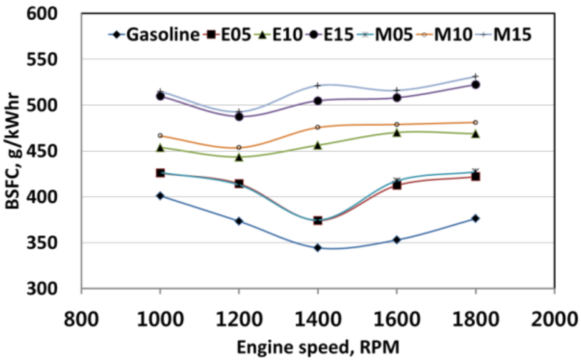

Figure 5: Brake specific fuel consumption versus engine speed for various fuels

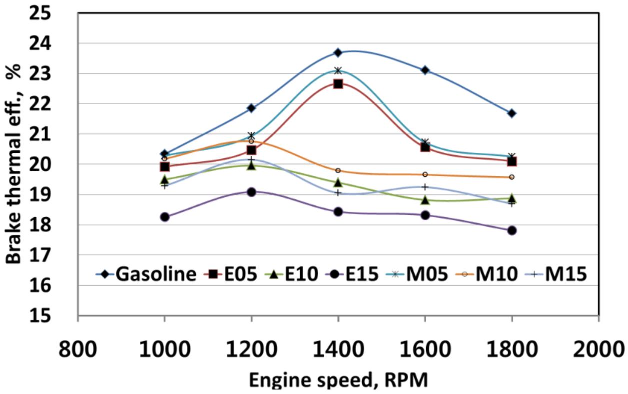

Figure 6: Brake thermal efficiency versus engine speed for various fuels

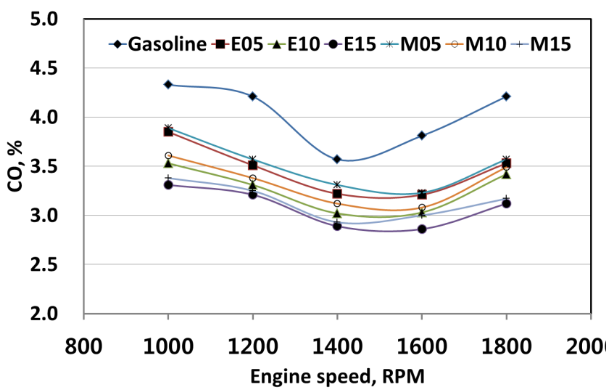

Figure 7: CO emissions versus engine speed for various fuels

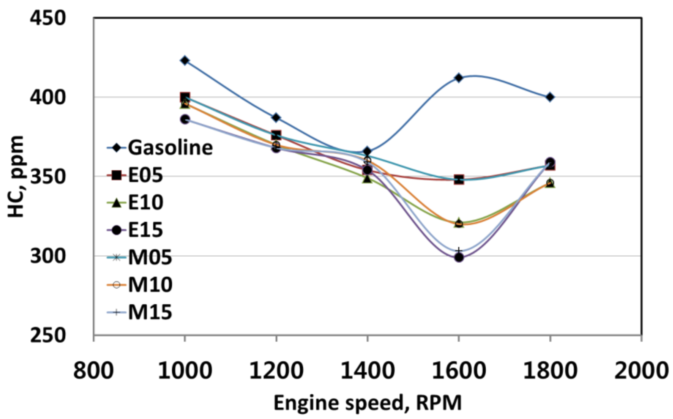

Figure 8: HC emissions versus engine speed for various fuels

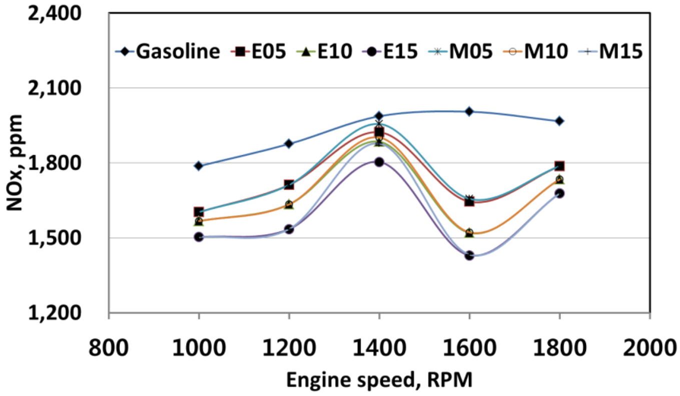

Figure 9: NOx emissions versus engine speed for various fuels

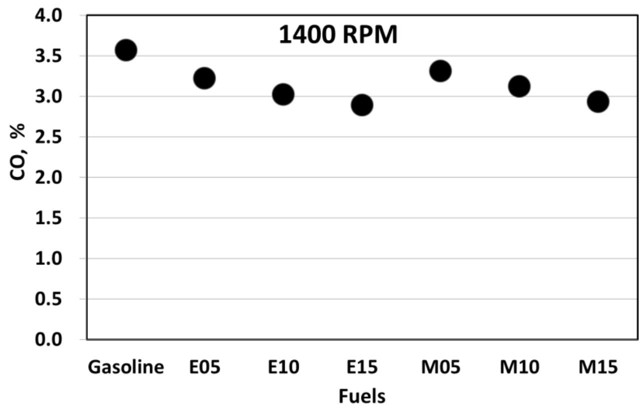

Figure 10: CO emissions versus various fuels at 1400 rpm

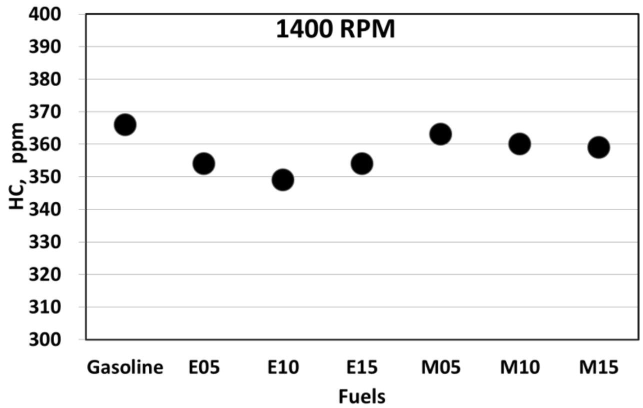

Figure 11: HC emissions versus various fuels at 1400 rpm

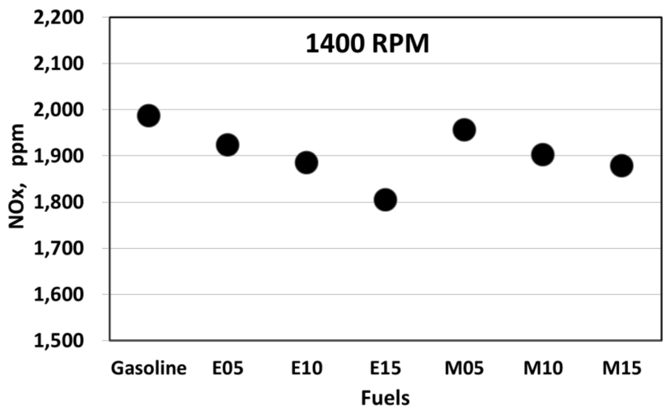

Figure 12: NOx emissions versus various fuels at 1400 rpm

Conclusions

Experimental results obtained by comparing and analyzing various performance characteristics and exhaust gas characteristics are as follows.

Regarding the change in engine speed, gasoline is the largest in torque, BMEP and engine output. Although there is a slight difference, when the amount of the mixture of ethanol and methanol is increased, the torque, BMEP and engine output tend to be reduced. The magnitude of torque, BMEP and engine power are M05, E05, M10, E10, M15 and E15. This main cause is considered as low calorific value.

The emission of CO, HC and NOx decreased rapidly as the ethanol and methanol contents increased. Especially, when ethanol and methanol were added to gasoline at 1,400 rpm, exhaust gas was found to be optimal. The order of the exhaust gases is E15, M15, E10, M10, E05, M05, which are the reverse order of torque, BMEP, and engine output trend. It was found that the exhaust gas effect was more excellent when ethanol was used as a whole than methanol.

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