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Experimental investigation of methanol dissociated gas addition to gasoline in a spark ignition engine

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Abstract. This work investigates the performances and emission characteristics of a spark ignition (SI) engine fuelled with methanol dissociated gas and gasoline mixtures. The dissociation system for methanol was designed, methanol dissociated gas was blended to the gasoline up to 20% by volume, and experiments were conducted within a four-cylinder, four-stroke and water-cooled spark ignition (SI) engine. Performance tests were carried out via measuring brake thermal efficiency, equivalent specific fuel consumption, and exhaust emissions (CO, HC, NOx) with a constant speed of 2000 rpm at stoichiometric condition. The results indicate that an increase in methanol substituted ratio has slightly lowered the engine torque. The addition of methanol dissociated gas decreases the equivalent specific fuel consumption and increases the effective thermal efficiency from the economical point of view. And the exhaust emissions decrease by about 33% and 28% of the mean average values of CO and HC emissions when the proportion of methanol substitution was 20% comparing to pure gasoline. However, nitrogen oxide emission values increased with the adding of methanol dissociated gas.

1. Introduction

Internal combustion engines are the most commonly used power source in vehicle engineering. They are largely dependent on fossil fuels, especially crude oil such as gasoline and diesel. However, the limit world's fossil fuels reserves would not meet the request of the increasing number of motor vehicle. The energy crisis and the restriction of oil drove many researchers to find alternative fuels with higher efficiency for transportation. In the last decade, electricity, hydrogen, liquid bio-fuels, natural gas, bio methane, synthetic fuels, paraffinic fuels and liquefied petroleum gas have been utilized to improve both performance and emission pollution of SI engine.

Alcohol fuels are considered in the previously investigation[1,2]. Methanol, which is the versatile alcohol fuel, can be obtained from a wide variety of sources such as coal, natural gas, biomass, and agricultural feedstock[3]. So it is considered as one of the alternative fuels to be added to gasoline to decrease the dependency on petroleum fuels. Compared to gasoline, methanol shows a great advantage for its economical efficiency, easy obtainment, better antiknock characteristics leading to a higher compression ratio, a higher laminar flame propagation speed making the combustion more efficiently under lean conditions than gasoline, and the lower carbon/hydrogen ratio reducing the emissions of hydrocarbon (HC) and CO. These combustion properties have made methanol a strong alternative fuel for SI engine applications.

Recently, several studies focus on using methanol in SI engines either pure or as a blending component. However, neat methanol has a cold-starting problem because of its high latent heat of

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vaporization, and an increase in formaldehyde emissions in exhaust can be limitation to prevent it from a motor fuel[4]. For the above reason, this work utilizes the methanol dissociated gas-gasoline instead of neat methanol in an SI engine in order to take advantages of methanol while avoiding parts of the shortcomings. The experimental study on engine power performance, combustion and emission will form highly valuable dataset for further study of SI engine using gasoline-methanol blends.

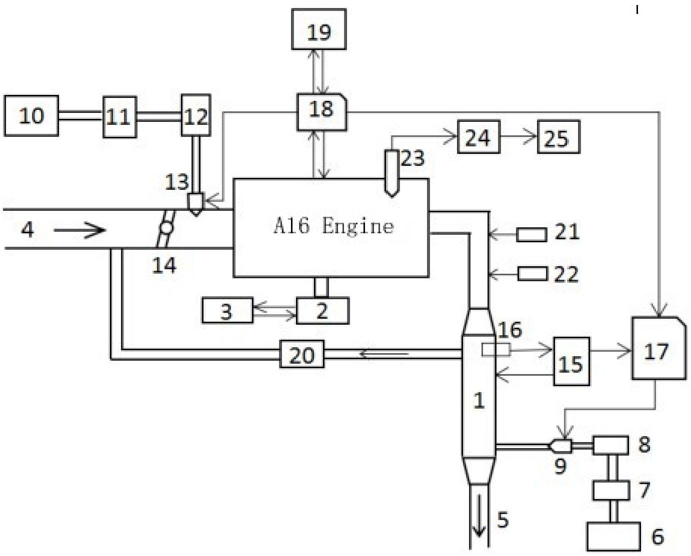
2. Experimental method

The test equipment consisted of a test engine, the measurements and some control units. The internal combustion engine is a 4-cylinder, four-stroke, water-cooled engine. Engine characteristics are given in Table 1. A view of the experimental setup is given in Figure 1. The schematic diagram of the experimental system is given in Figure 2.

Table 1. Engine characteristics

Engine Item	Value
Cycle	4
Number of cylinders	4
Bore×stroke (mm)	78.5 × 82
Displacement (L)	1.587
compression ratio	10.5
Rated Power (kw)	78
Max Torque (N·m)	142

Figure 1 A view of experimental setup



1-Methanol dissociated reactor; 2-Dynamometer; 3- Controller; 4-Intake; 5-Exhaust; 6-Methanol tank; 7- Methanol flowmeter; 8-Methanol pump; 9-Methanol injector; 10-Fuel tank; 11-Fuel flowmeter; 12-Fuel pump; 13-Fuel injector; 14-throttle valve; 15- Temperature Controller; 16-Temperature sensor; 17-Control unit of Methanol injector; 18-ECU; 19-Computer; 20-Gas flowmeter; 21-Oxygen sensor; 22-Exhaust gas analyzer; 23-Pressure transducer; 24-Charge Amplifer; 25-Data logger

Figure 2 Experimental setup

In this study, blended fuels were prepared by adding different volume fraction of methanol to a commercial gasoline (RON = 95). Before applying fuel blends to engine, we run the engine long enough to consume the remaining fuel in the previous experiment and produce high-temperature exhaust gas. When the dissociated reactor was heated to 550K, the methanol was pumped to the reactor at a speed of 1.2kmkm/h and dissociated by using Zinc-Copper as catalysts. The dissociated gas consisting of 60.7%-64.8 H_2, 19.1%-23.1% CO, and other by-product such as CH_3OCH_3, CO_2, CH_4, HCO_2CH_3, CH_2O and unburned CH_3OH was then introduced into the intake parts before the cylinder.

The tests were carried out at stoichiometric conditions and 2000 rpm engine speeds under different loads for the volumetric gasoline-methanol blends (5%, 10 %, 15% and 20%). The experimental data were recorded after the engine had reached the steady operation conditions. The brake torque, the flow rate of fuel, and the mass flow rate of air were measured during the experiments, and these measured parameters have been used to calculate the engine performance parameters.

3. Results and discussion

3.1 Performances analysis

The conception of methanol substituted ratio (l) was calculated using the following formula:

$$l = \frac{H_{lm} \times G_m}{H_{lm} \times G_m + H_{\lg} \times G_g} \qquad (1)$$

The conception of equivalent fuel consumption (b_{eq}) was calculated using the following formula:

$$b_{eq} = \frac{H_{lm} \times G_m + H_{\lg} \times G_g}{H_{\lg} \times P_e} \qquad (2)$$

where H_{lm} is the Low heat value of methanol, H_{lg} is the Low heat value of gasoline, G_m and G_m are the consumption of methanol and gasoline, respectively, P_e is the output power of the engine.

Figure 3 shows the effects of methanol substituted ratio (MSR) on engine torque at engine speed of 2000 rpm and throttle opening percentage of 17%. It can be seen that with the increase in the value of MSR, the torque has fallen. For pure gasoline, the output torque was 60 N·m. When the MSR reaches 50%, the engine has the lowest output torque of 55.9 N·m, decreased the output by 6.8%. The result indicates that with the increase fraction of methanol, engine power and torque decrease. The reason can be concluded as follow: The test was conducted at a fixed air intake quantity (throttle opening percentage at 17%) dissociated gas contains a large part of hydrogen, whose density is much less than air. So the dissociated gas occupies a part volume of cylinder and decrease the air inflow at each cycle. While the engine is working, each working condition is adjusted by decreasing the fuel injection to keep the engine operating at stoichiometric condition, and it leads to a fallen of torque.

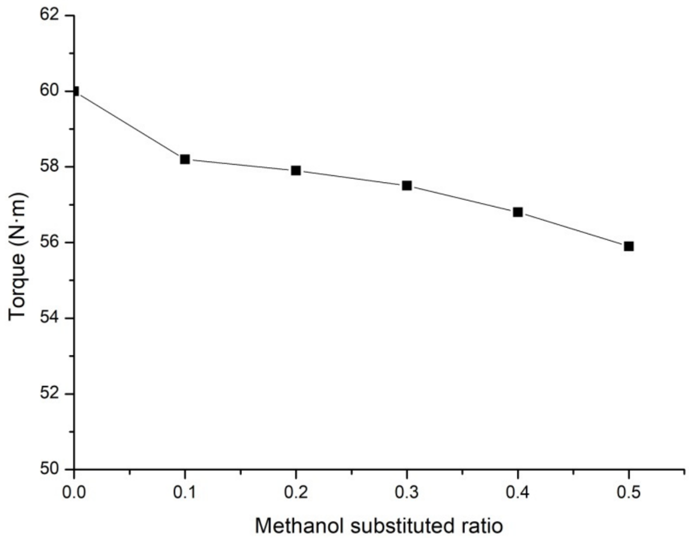


Figure 3 Effect of methanol substituted ratio on the engine torque

3.2 Economical analysis

The equivalent fuel consumption (EFC) versus the torque for various fuel mixtures has been illustrated in Figure 4. It can be seen that the addition of methanol amount helps decrease the EFC values. The highest EFC was obtained for pure gasoline, and The MSR20 has the least EFC compared to other fuel mixtures.

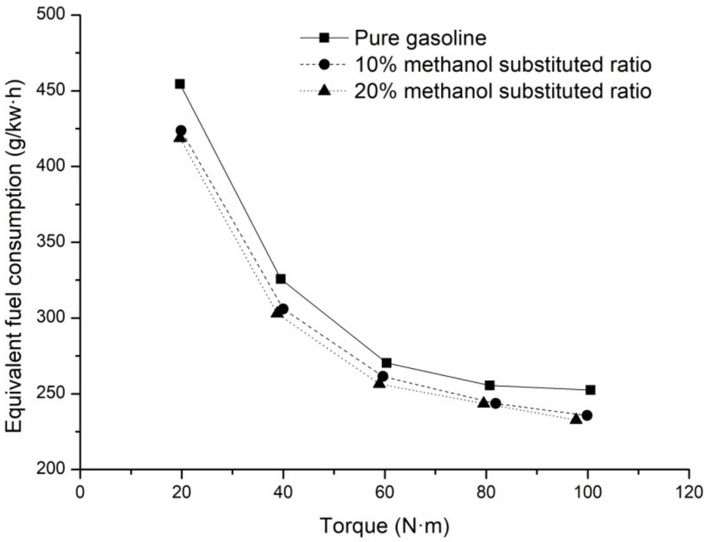


Figure 4 Equivalent fuel consumption values

The brake thermal efficiency (BTE) versus engine torque for various fuel mixtures has been shown in Figure 5. The BTE values increase with an increasing methanol ratio. The M20 performs best among the blends and gasoline for the tested engine torque. The lowest BTE was obtained with pure gasoline. This variation outcome on the improving combustion efficiency is especially due to the presence of oxygen in methanol

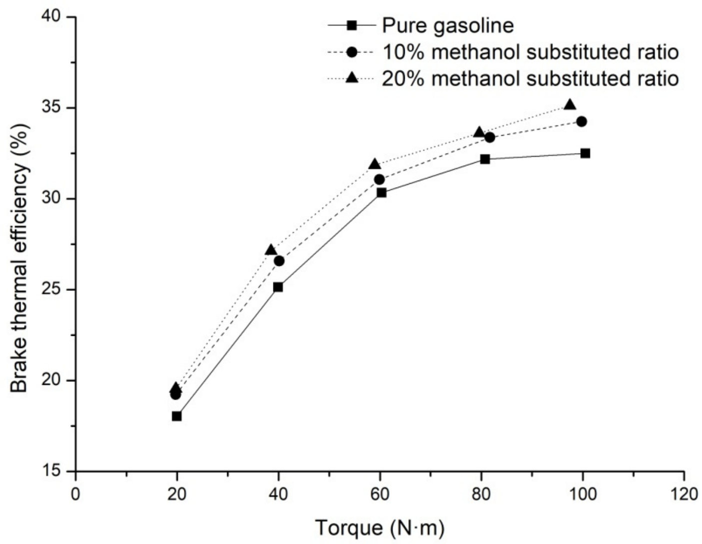


Figure 5 Brake thermal efficiency values

3.3 Emissions analysis

Figure 6 shows the variations of CO emissions for different methanol substituted ratio (MSR). It can be seen that as the percentage of dissociated gas increases, the CO emission decreases when the MSR is less than 10%; the CO emission does not change greatly when the MSR lies between 10% and 17%;

and the addition of methanol helps increase CO emissions as the MSR more than 17%. The decrease of CO can be explained by the fact that methanol is rich in oxygen. The increase in the oxygen ratio allows the CO to undergo more oxidation to produce CO_2. The cause of the increase is the fact that the hydrogen in the dissociated gas consumes the oxygen faster than gasoline, which leads to an incomplete combustion in some locals of engine as the MSR over 17% and increase the CO emission.

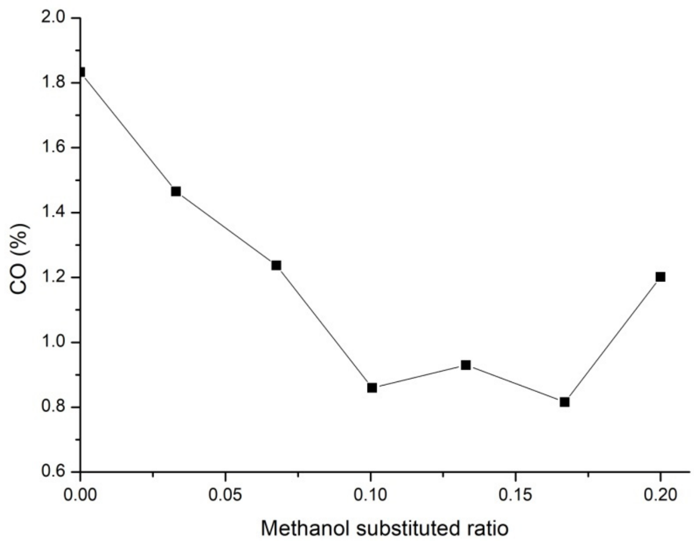


Figure 6 CO emission at different methanol substituted ratios

Figure 7 indicates changes in HC emissions with methanol substituted ratio. We can see that the addition of methanol decreases the HC emissions. The reasons for the reduction in HC emissions are that the amount of carbon in methanol is low and the combustion quality is improved by the presence of oxygen in the structure; besides, the diffusion coefficient of hydrogen in dissociated gas is more than gasoline, which helps to create a homogeneous mixture to improve the combustion in engine.

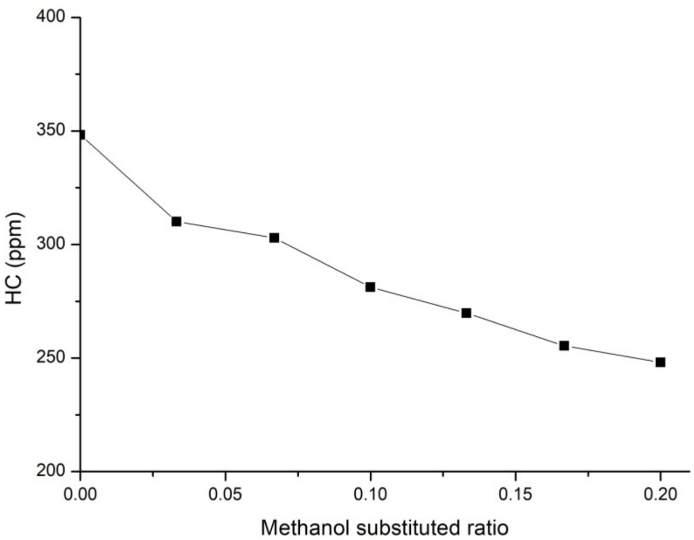


Figure 7 HC emission at different methanol substituted ratios

Figure 8 demonstrates the variation of NOx emissions for different methanol substituted ratio. It can be seen that the addition of methanol increases the NOx emissions. Since the presence of more oxygen in the methanol, it reacted with the nitrogen in the air at high temperatures, producing large amount of NOx. Another reason is that the hydrogen has a higher flame temperature than gasoline, the addition of hydrogen tends to cause more NOx emissions for SI engine.

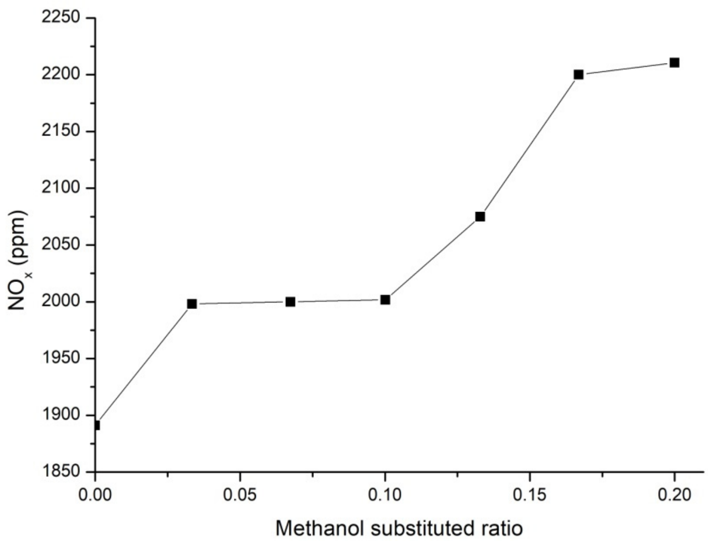


Figure 8 NOx emission at different methanol substituted ratios

4. Conclusions.

In this study, emissions and performance of an SI engine at 2000 rpm engine speed and different engine loads have been experimentally investigated fuelled by gasoline and methanol dissociated gas mixtures. Experimental results of this study can be summarized as follows:

- Methanol-gasoline blends have slightly lowered the engine torque. And the torque decreases with an increase in methanol substituted ratio.
- Methanol-gasoline blends greatly enhance the brake thermal efficiency values compared to pure gasoline. Increases in the addition methanol ratio have increased the brake thermal efficiencies for all blends.
- The addition of methanol decrease the CO emission at MSR<10%; the CO emission does not change greatly at 10%<MSR<17%; and the addition of methanol increase CO emissions at 17%<MSR.
- The addition of methanol decreases the HC emissions by 28% comparing to pure gasoline when the proportion of methanol substitution was 20%.
- The addition of methanol increases the NOx emissions by 19% comparing to pure gasoline when the proportion of methanol substitution was 20%.

It can be concluded that it is possible to use methanol dissociated gas as a supplementary fuel for SI engine application.

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