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A Study on Emissions and Catalytic Conversion Efficiency Characteristics of an Electronic Control Engine Using Ethanol Blended Gasoline as Fuels

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Abstract : In this paper, the effects of ethanol blended gasoline on emissions and their catalytic conversion efficiency characteristics were investigated in a multiple-point EFI gasoline engine. The results show that with the increase of ethanol concentration in the blended fuels, THC emissions were drastically reduced by up to thirty percent. And brake specific fuel consumption was increased, but brake specific energy consumption could be improved. However, unburned ethanol and acetaldehyde emissions increased. Pt/Rh based three-way catalysts were effective to reduce acetaldehyde emissions, but had low catalytic conversion efficiency for unburned ethanol. The effect of ethanol on CO and NOx emissions and their catalytic conversion efficiency had close relation to the engine's speed, load and air/fuel ratio. Furthermore fuels blended with thirty percent ethanol by volume could dramatically reduced THC CO and NOx emissions at idle speed.

Key words : EFI(Electrinic fuel injection), Ethanol, Emission, Catalytic converter

1. Introduction

Since tetraethyl lead as gasoline's octane improver was banned in the United States on the first day of January in 1996, Oxygenates have been used to enhance gasoline's octane number and reduce air pollution (summertime smog, wintertime carbon monoxide, volatile organic compounds) with provision for more complete fuel combustion in engines. Methyl tert-butyl ether (MTBE) is the most preferred oxygenate by refiners because of its low cost, ease of production of reformulated gasoline(RFG) mandated in the Clean Air Act Amendments of 1990 and similar regulations set forth by the California Air Resources Board.

Over 85% of RFG used in the U.S. contains MTBE and approximately 8% contains ethanol. The remaining 7% of RFG contains a combination of other oxygenates(Methanol, ETBE).

By 1998, MTBE was ranked fourth in bulk chemical production in the United

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States[1]. However, MTBE in highly soluble in water and low levels of it make drinking water supplies unpalatable due to its low taste and odor threshold. And MTBE much more resistant to biodegradation than other gasoline components. Because of the increased and widespread use of MTBE, it has been detected in many parts of hydrologic cycle such as surface water and ground water. Moreover, MTBE itself can be present in exhaust gas and it has effects on eyes or lungs in regions using MTBE as gasoline additive[2]. When research animals inhaled high levels of MTBE.

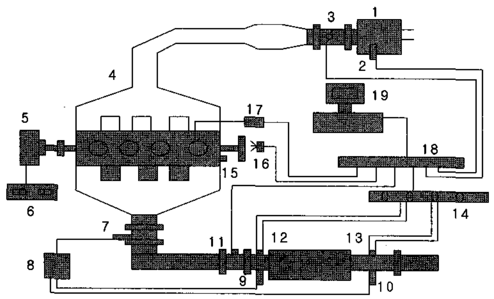
They have developed cancers or experienced other non-cancerous health effects. Although the data available is not adequate to estimate potential health risks of MTBE at low exposure levels in drinking water, MTBE poses a potential for carcinogenicity to humans at high doses. Even though MTBE is still being widely used, the momentum to phase out or reduce its usage is growing. Therefore, it appears desirable that research should continue to investigate possible oxygenate alternatives that have limited logistical and technical disadvantages.

Ethanol was first suggested as an automotive fuel in USA in the 1930s, but was widely used only after 1970. Nowadays, ethanol as a renewable fuel is used as fuel, mainly in Brazil, or as a gasoline additive for octane enhancement and better combustion, mainly in USA and Canada. The use of ethanol to substitute MTBE in reformulated gasoline would have some benefits on terms of water contamination and there were no significant adverse impacts in public health and environment[3]. Oxygen content of ethanol is approximately twice that of MTBE: consequently, less ethanol is required to meet specified oxygen content. Addition of oxygen to gasoline not only influences its oxygen content and cause changes in other fuel properties, but also alters distillation curve and dilutes other species in the gasoline and changes exhaust emissions [4]. Although ethanol addition into fuel may contribute to a reduction in hydrocarbon and carbon monoxide emissions, higher ethanol and acetaldehyde emissions could be emitted[5]. Moreover, Gasoline blended with ethanol has a higher RVP than MTBE blended gasoline. Additional costly steps are needed to reduce the RVP of base gasoline to which ethanol is added per liter to the existing RFG. Pumphrey et al. studied vapour pressure of the alcohols-gasoline blends at 37.8℃ as a function of mixture composition. The vapour pressure of the alcohol blended gasoline fuels was initially elevated and then lowered as the concentration of alcohols was increased to a certain degree. As to ethanol, its vapour pressure is higher than that of gasoline if the concentration of ethanol in the blended fuels is less than 65% by mole, indicating increased evaporative emissions from ethanol blended gasoline fuels[6].

Ethanol can be obtained from biomass The most important aspect is that the CO_2 released by ethanol combustion has been fixed recently by growing plants and therefore this greenhouse gas makes no net contribution to global warming[7]. Oxygen concentration of ethanol is about 34.8% by weight, but the heating value is only 61% that if gasoline. When the amount of ethanol in blended gasoline increases, the heating value if ethanol blended gasoline fuels will decrease.

2. Experimental Equipment and Procedure

The engine used in this experiment is a multiple-port EFI gasoline engine with cylinder bore and stroke of 90.82mm and 76.95mm, respectively. Its compression ratio is 8.2 and its rated power is 66kW at 5000rpm. The maximum torque is 150Nm at 3000rpm. When the engine operates at part load, the fuel injection system will be worked in close-loop control. And it will be operated in open-loop control at full load. A Pt/Rh based three-way catalytic converter is fixed in the tail pipe.



1.Air cleaner 2. AFS 3. Throttle valve 4. Inlet valve 5. Dynamo meter 6. Dynamo controller 7.Thermo couple1 8.Temp. controller 9.Thermo couple2 10.Thermo couple3 11.O_2 Sensor 12.1st Emission gas 13.2nd Emission gas 14. Emission analyzer 15. Crank Angle Senser 16. Encoder 17. Amp. 18. A/D converter 19. PC

Fig. 1 Schematic diagram of engine test apparatus

In the experiment, the concentration of THC, CO, NOx and CO_2 is measured on line with an AVL exhaust analyzer. THC emissions are analyzed with flame ionization detector (FID). CO and CO_2 emissions are analyzed with non-dispersive infrared analyzer (NDIR) and NOx emissions are measured with chemiluminescent detector(CLD). Unburned ethanol and acetaldehyde are also analzed by a GC-17A gas chromatography.

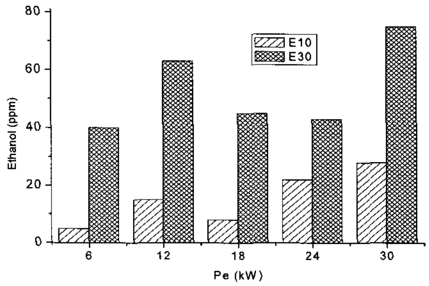
Three test fuels were used in this study. The first one was unleaded gasoline with an octane number of 90(called E0) as a basic fuel for the preparation of gasoline/ethanol blend. The second ethanol (E30) respectively. Their effects on emissions and catalytic conversion efficiency were investigated in an EFI gasoline engine without any modification.

3. Experimental Results and Discussions

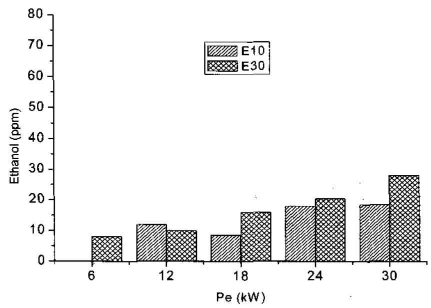
3.1 Unburned Ethanol and Acetaldehyde Emissions Using Ethanol Blended Gasoline Fuels

Unregulated emissions such as unburned ethanol and acetaldehyde were measured in the investigation. Unburned ethanol emissions were given in Fig. 2 As shown, the engine emitted unburned ethanol at various conditions, and unburned ethanol had low conversion efficiencies in catalyst.

Acetaldehyde emissions were illustrated in Fig. 3 ethanol blended gasoline fuels were used. Acetaldehyde emissions before catalytic converter increased as the amount of ethanol on the blended fuels increased at 2000 rpm and reached their maximum emissions. Meanwhile, acetaldehyde emissions decreased as the load increases when E0 was used, which meant that acetaldehyde emissions converted from ethanol was high at medium load. Acetaldehyde emissions after catalytic converter were low except that E10 was used. Those results showed that Pt/Rh based catalysts were effective to reduce acetaldehyde emissions at 2000 rpm Emissions using E30 were almost two times than that when E10 was used. As to acetaldehyde conversion. Pt/Rh based catalysts were effective to reduce acetaldehyde emissions.

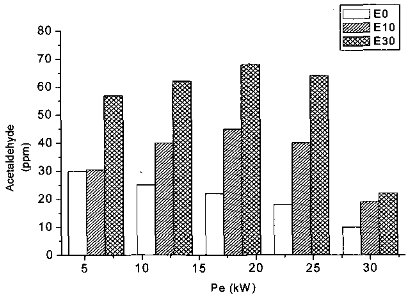


(a) Before the converter

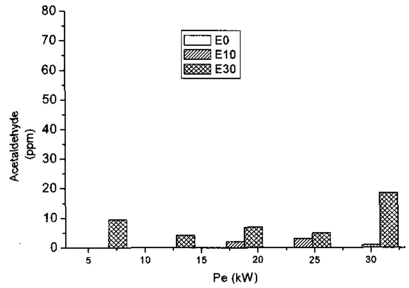


(b) After the converter

Fig. 2 Unburned ethanol emissions before and after catalytic converter at 2000 rpm

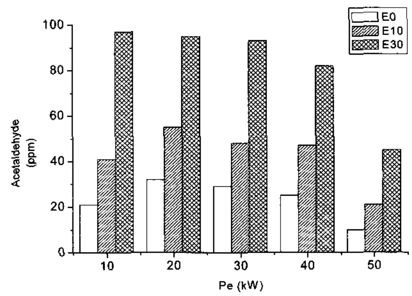


(a) Before the converter

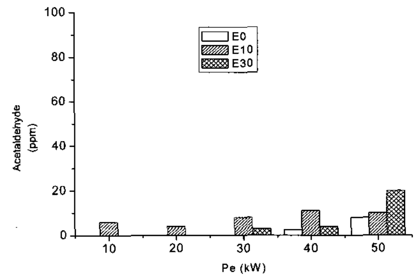


(b) After the converter

Fig. 3 Acetaldehyde emissions at 2000 rpm



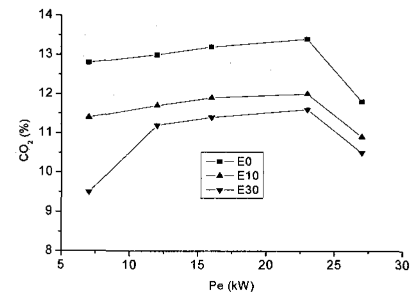
(a) Before the converter



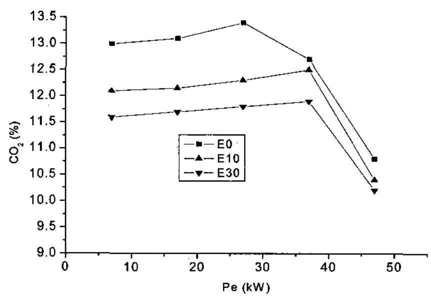
(b) After the converter

Fig. 4 Acetaldehyde emissions at 3000 rpm

3.2 CO_2 Emissions



(a) Before the converter(n=2000rpm)



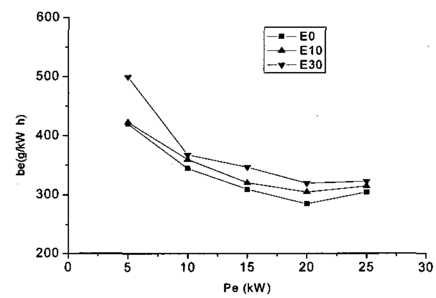
(b) Before the converter(n=3000 rpm)

Fig. 5 CO_2 emissions at different conditions

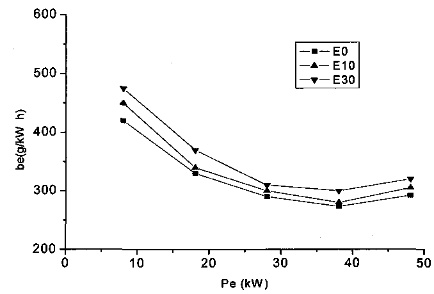
CO_2 is one of green houses emitted from engine. And CO_2 emissions have close relation with fuel's properties and combustion. CO_2 emissions were illustrated in Fig. 5 CO_2 emissions before catalytic converter reduced as the amount of ethanol in the blended gasoline fuels increased. Ethanol could decreased CO_2 emissions by 7~11% and 10~22% when E10 and E30 were used respectively at the same load and speed. While CO_2 emissions were reduced by 2~7% and 6~10% at 3000 rpm. The reason is the fact that in the case of E0, E10 and E30, the ratios of carbon to hydrogen by weight are 6.308, 6.608 and 5.598 respectively. The addition of ethanol to gasoline decreases carbon content in the blended fuels and improves the engine's thermal efficiencies.

3.3 Brake Specific Fuel Consumption

Brake specific fuel consumption (BSFC) was presented in Fig. 6 When ethanol blended gasoline fuels were used. Since Ethanol has low heating value, BSFC was increased with the increase of ethanol in the blended fuels.



(a) n=2000 rpm

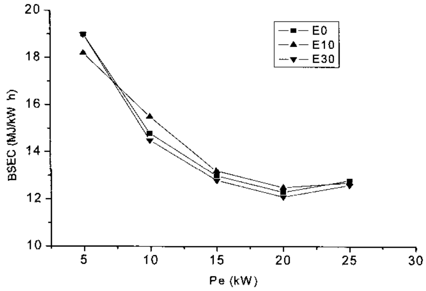


(b) n=3000 rpm

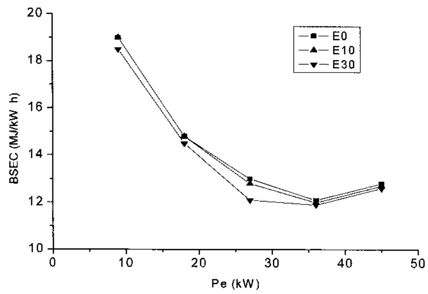
Fig. 6 Brake specific fuel Consumption (BSFC) using ethanol blended gasoline fuels

Brake specific energy consumption (BSEC) was illustrated in Fig. 7 BSEC got better with the increase of ethanol except that E10 was used at 2000 rpm.

The maximum improved level of BSEC was near 4% when E30 was used, which proved that ethanol could improve combustion.



(a) n=2000 rpm



(b) n=3000 rpm

Fig. 7 Brake specific energy consumption using ethanol blended gasoline fuels

3.4 NOx, CO and THC emissions at Idlle Speed

Emissions at idle speed using ethanol blended gasoline fuels were presented in Fig. 8. The emissions using E0 were assumed 100 percent. The emissions using E10 and E30 were relative values to pure gasoline. Ethanol could improve CO, THC and NOx emissions. CO, THE and NOx were reduced by 35.7%, 53.4% and 33% respectively using E30. And the improved levels were vetter than that using E10

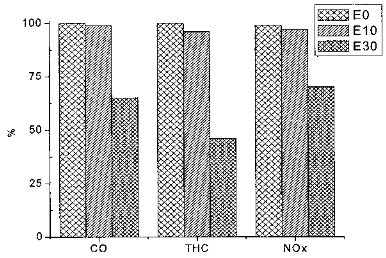


Fig. 8 Effect of ethanol blended fuel on the exhaust emission at idle speed

4. Conclusions

From the discussions above, we can conclude that :

(1) Ethanol had little effect on the reduction in CO at part load, but CO emissions could be improved at full load with the increase of ethanol. Moreover, Pt/Rh based three way catalytic converter had little effect in CO conversion efficiency.

(2) The addition of ethanol to gasoline could improve THC emissions significantly. The maximum reduction can be reached by almost 3%. But THC conversion efficiencies were decreased when high amount of ethanol blended gasoline fuels were used.

(3) Ethanol could improve NOx emissions at part load, but its advantages in NOx reduction disappeared at full load. And Pt/Rh based three-way catalytic converter had little effect in NOx reduction.

(4) Compared with E0 at idle speed, E10 had little effect in CO, THC and NOx emissions reduction. But E30 could improve CO, THC and NOx emissions significantly. The maximum reduction

in THC emissions was up to 53.4%.

(5) Unburned ethanol in the exhaust increased as the content of ethanol increased. And Pt/Rh based catalytic converter could not convert it effectively.

(6) Acetaldehyde emissions in the exhaust increasedas ethanol content increased. But the conversion efficiency for acetaldehyde was high.

(7) The addition of ethanol to gasoline could reduce CO_2 emissions, and the reduction in CO_2 became more obvious as the amount increased in the blended fuels.

(8) BSFC increased as ethanol content increased, but BSEC could be improved.

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