

High Concentration Ethanol Effect on SI Engine Emission

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ABSTRACT

From the energy security and CO₂ reduction point of view, much attention has been paid to the usage of bio-fuel. Recently, highly concentrated ethanol is used in some areas ("E85"; 85% ethanol and 15% gasoline in North America and Sweden, and "ethanol"; 93% ethanol and 7% water in Brazil). In these regions, Flexible Fuel Vehicles FFVs are being introduced that are capable of using fuels with a wide range of ethanol concentrations. Advantages of highly concentrated ethanol in internal combustion engine applications are higher thermal efficiency obtained due to higher octane number, and a reduction of nitrogen oxides due to lower combustion temperatures. On the other hand, the latent heat of vaporization for ethanol is greater than gasoline, causing poor cold startability and high NMOG emissions.

This paper examines the effect of highly concentrated ethanol on exhaust emissions at cold start in a SI- engine. In first, by using gas sampling and computational simulation in-cylinder at the peak compression, quantity and composition of evaporated highly concentrated ethanol fuel are analyzed at cold temperatures, which is a determining factor for startability and exhaust emissions. And, technical guidelines for reducing exhaust emissions are defined from the viewpoints of fuel properties requirements such as concentrations and saturated vapor pressures of ethanol, and fuel evaporations improvement by utilizing variable valve train and heating device.

INTRODUCTION

Recently, ethanol, ethanol-gasoline mixtures and ethanol-petrochemical gas compounds, such as ETBE (ethyl tertiary butyl ether), are being used as fuels for spark ignited engine applications. Table 1 indicates the characteristics of ethanol.

The use of concentrated ethanol fuel in internal combustion engine applications has advantages when compared with gasoline. These include increased thermal efficiency obtained due to higher octane, and a reduction of nitrogen oxide emissions from lower combustion temperatures.⁽¹⁾ On the other hand, the latent heat of vaporization for ethanol is greater than gasoline, causing poor NMOG emissions performance and cold startability ^{(2),(3),(4),(5)} (Figure1,2).

Table.1. Properties of Ethanol and Gasoline

Property	Ethanol	Gasoline
Formula	C ₂ H ₅ OH	C ₄ ~ C ₁₂
Density (g/cm ³)	0.789	0.737
Low calorific value (MJ/kg)	26.8	43.1
Stoichiometric air-fuel ratio	9.0	14.6
Boiling point (degC)	78.5	30 ~ 180
Research Octane Number	111	92
Latent heat of evaporation (kJ/kg)	845	420

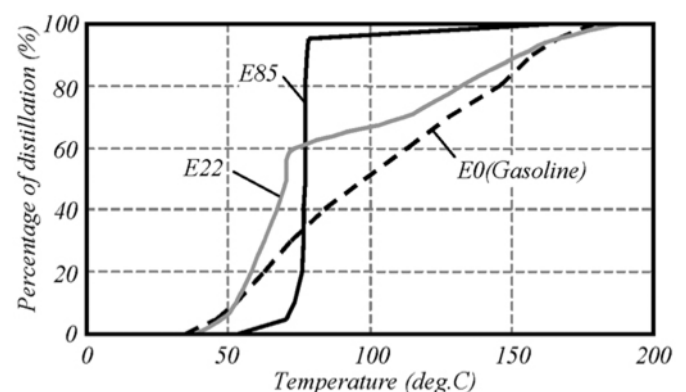


Fig.1. Distillation Properties

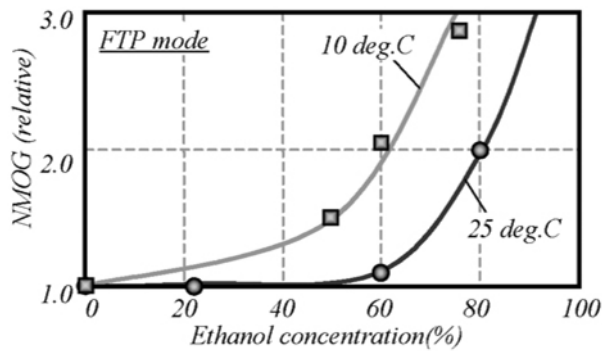


Fig.2. Relation between ethanol content and NMOG emissions

In most areas of the world, ethanol-gasoline bio-fuel is used with an ethanol concentration of only up to 10%. The disadvantages of using ethanol fuels listed above are minimized when using such a low ethanol concentration. However, in some regions, blended fuel of high ethanol concentrations is used. (E85; 85% ethanol and 15% gasoline in North America and Sweden, “E100”; 93% ethanol and 7% water in Brazil). Figure 3 illustrates the global ethanol blend fuel market. In high ethanol content fuel regions, Flexible Fuel Vehicles (FFVs) are being introduced that are capable of running on fuels with a wide range of ethanol concentrations.

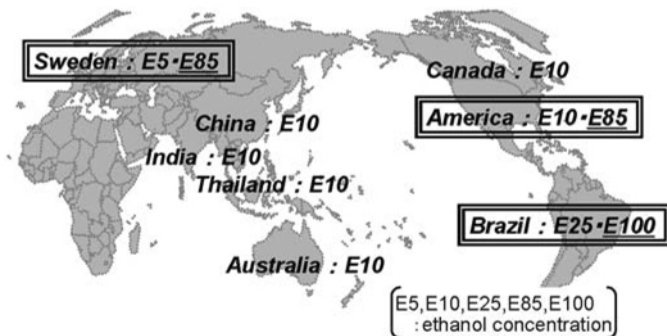


Fig.3. Markets of Ethanol Fuel

This Paper quantitatively analyzes the evaporation of highly concentrated ethanol at cold temperatures, which directly affects for SI engine exhaust emissions.

EXPERIMENTAL CONDITION

TEST FUEL SPECIFICATION

Engine tests were performed using an inline 4 cylinders engine with a displacement of 2.0L. Table 2 details the specifications of the test engine. To investigate Cold Emissions performance, the E0 (Regular Gasoline) and E85 (Class1 in the ASTM classification) fuels shown in Table 3 were examined.

Table.2. Engine Specifications

Engine Type	4-stroke, 4-cylinder 4-valve DOHC
Cylinder bore, mm	80.5
Piston stroke, mm	97.6
Compression Ratio	10.0 : 1
Piston displacement, cc	1986
Fuel Injection System	MPI
Intake Valve Open,deg.BTDC	7
Intake Valve Close,deg.ABDC	67
Exhaust Valve Open,deg.BBDC	60
Exhaust Valve Close,deg.ATDC	-1

Table.3. Characteristics of Test Fuel

Test fuel	Fuel 1	Fuel 2
Classification of Test Fuel	Regular	ASTM Class1
Elements (vol.%)	Ethanol	0
	Gasoline	100
	Butane	0
	Water	0
Reid vapor pressure (kPa)	63.0	51.5
Stoichiometric air-fuel ratio	14.6	9.96
Density(g/cm ³)	0.737	0.781
Low calorific value(MJ/kg)	43.1	29.6

EXPERIMENTAL DEVICE

To investigate the evaporation characteristics of fuel in the test engine cylinders, a gas-sampling device was installed in the combustion chamber near the spark plug. This device allows measurement of the in-cylinder air-fuel ratio at peak compression along with the hydrocarbon composition of the fuel vapor.

For in-cylinder air-fuel ratio measurement, a high response analyzer (CSV500 and HFR-500 by Cambustion Ltd.) was used. The sampling pipe, which is part of the spark plug, is connected to a high response FID. The gas sampling method for the engine in Table 2 is illustrated in Figure 4. The gas around the plug flows up the sample tube, through an electromagnetic valve and into a seizure pipe. The electromagnetic valve only opens for a limited time at TDC, based on a trigger signal from the crankshaft. The sample gas enters through the seizure pipe, due to the pressure differential between the combustion chamber and the outlet of the seizure pipe. The sampled gas is analyzed using gas chromatography, and the component ratio of vaporized fuel is calculated.

