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An Investigation of HCCI Engine Combustion and Emission Characteristics on Fuel Properties.

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Abstract

The main purpose of the study is to investigate the ideal manner and ratio to inject gasoline and DME simultaneously into intake port, and moreover to confirm the characteristics of combustion and emission of engine. Experimental conditions are 1200 rpm, compression ratio 8.5, intake air temperature(110^{O}C). Internal cylinder pressure was collected to confirm the characteristics of combustion in order to calculate the heat release rate in the cylinder. In addition, HORIBA (MEXA 7100) which was possible analyzing emissions (NOx, CO, HC) was used. Vanguard gasoline engine (23HP386447) was used in this experiment.

Keywords*:* Dimethyl ether, Gasoline, Homogeneous charge compression ignition, Low temperature oxidation

1. Introduction

HCCI engine has the advantage of low emissions (NOx and particulate matter) and high efficiency. HCCI engine is expected to have a higher efficiency than SI engines and less emission than CI engines; it is possible to replace the conventional internal combustion engine. In addition, HCCI engine which operate without a high-pressure fuel injection system may be price competitive and use a variety of fuels.

However, there are many problems to be stable HCCI engine operating yet. One of the problems is to control the combustion phase. Another obstacle is the unburned hydrocarbons and incomplete combustion due to low temperature lean combustion generates carbon monoxide.

Additionally, heat release occurs very rapidly because the mixture autoignites simultaneously at multiple locations in the cylinder. As a result, the combustion process lacks quietness and there is a likelihood of abnormal combustion occurring in the high load region, this study focused on the use of a two-component fuel blend.

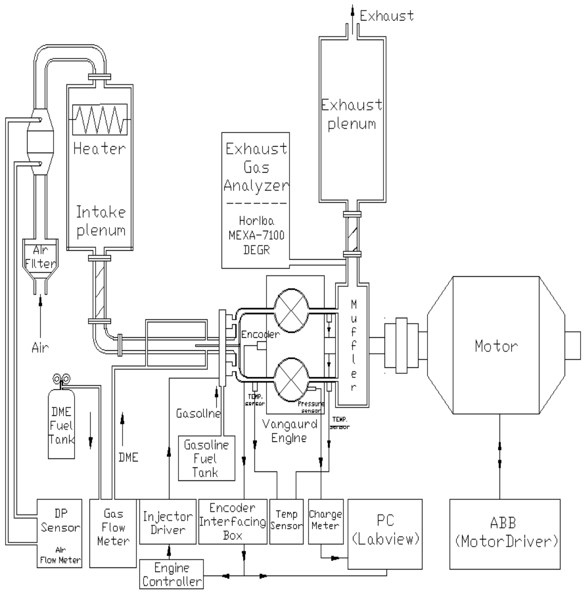

Fig.1 experimental apparatus

Table. 1 Engine specification

Displacement (single-cylinder) [liters]		0.313
Bore × Stroke [mm]		75.5×70
Connecting Rod Length [mm]		105
Compression ratio		8.4
Number of valves		1 intake, 1 exhaust
IVO	bTDC	44
IVC	aBDC	82
EVO	bBDC	96.5
EVC	aTDC	64.5
Fueling system		Fully Premixed
Engine Speed [rpm]		1200

On the other hand, by the design of fuel, the techniques of controlling auto-ignition timing and avoiding knocking are also advanced for investigation. The fact that the heterogeneity of the fuel/air mixture slows combustion reaction speed was reported with the result of the chemiluminescence measurement in the combustion chamber. In other words, it is possible to lower the maximum of heat release and to lengthen combustion duration by introducing the heterogeneity.

From this knowledge, it is thought that introduction of the heterogeneity of the fuel/air mixture is a means effective in the avoidance of knocking in HCCI engine.

Table. 2 Fuel properties

	DME	Gasoline
Chemical structure	CH3OCH3	-
Cetane / Octane number	>> 55	91~93
Vapor pressure (20℃) [MPa]	0.51	-
Auto-ignition temperature [K]	508	773
Low heating value [MJ/kg]	28.8	43.2
Liquid density [kg/m3]	667	750
Oxygen content [%]	34.8	<2.3

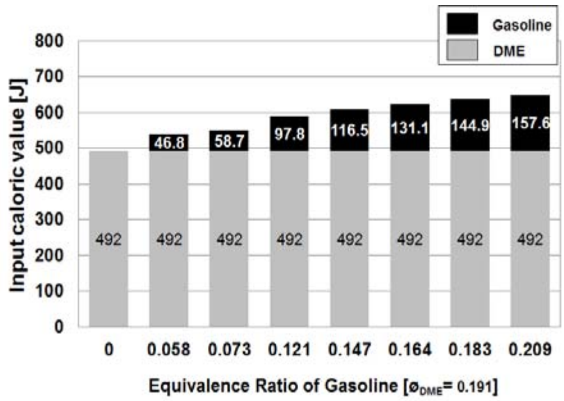

Fig.2 Fuel mixing ratio

2. Experimental apparatus and Method

2.1. Experimental Apparatus

The engine used in this study is one of the Vanguard engine. The specifications of the engine are shown in Table 1, and the experimental apparatus in Fig. 1. The fuel supply system was the port injection for well-premixed fuel and then the intake temperature was controlled at 383 K by using a heater of the intake tank. The distance between the injection position and the intake valve was approximately 260 mm. The fuel injection rate was constantly controlled by using HSP-2-- II model on the basis of a minute. The engine controller (Zenobalti Co.; ZB-8035),

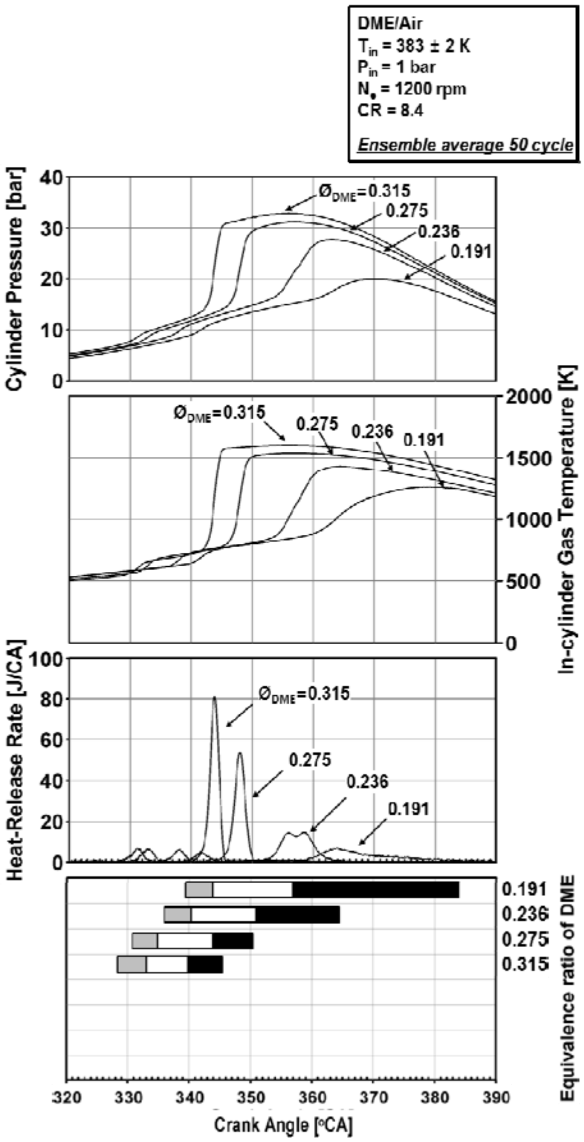

Fig.3 DME HCCI combustion characteristics with various intake temperature

Rotary encoder (Autonics; E40S), Encoder interface (Zenobalti Co.; ZB-100) and injecter driver (Zenobalti Co.; ZB-5100) were used for the purpose of controlling injection timing. The controls of engine speed and load condition were maintained by an inverter type dynamometer (ABB Co.; ASC800) which was connected to the crankshaft. The in-cylinder gas pressure was measured with a piezoeletric pressure transducer (Kistler; 6056A) at intervals of 0.1 CA. The concentration of THC, CO and NOx were measured by the exhaust gas analyzer (HORIBA; MEXA-7100 DEGR). All measured concentrations

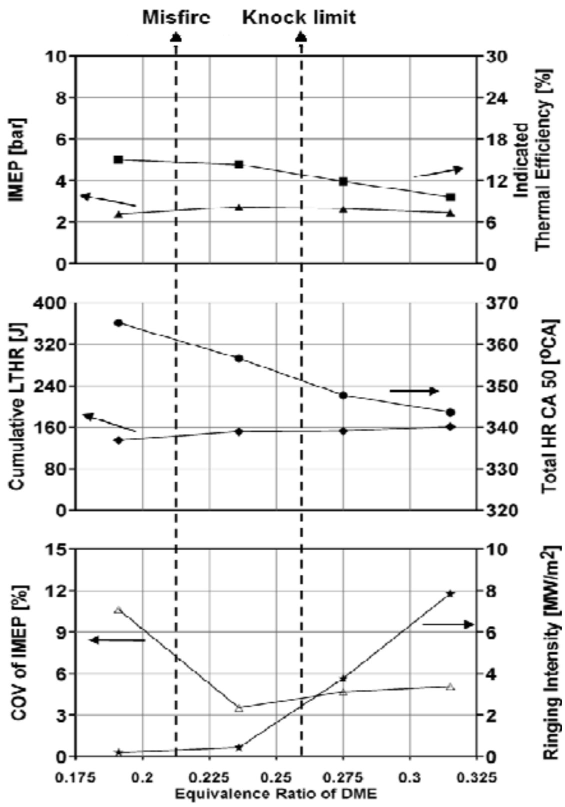

Fig. 4 Ringing intensity and in-cylinder gas maximum temperature with various intake temperature

of THC, CO and NOx were the mean values at interval of a minute only under steady state condition.

2.2. Experimental Method

The intake temperature for DME HCCI combustion was increased at low compression ratio. At the compression ratio of 8, the experiments were conducted by decreasing the temperature from 434K to 363K. Through the above experiment ground which is 383K of intake temperature, this study implements to find out the characteristics of combustion and exhaust of HCCI engine by gasoline mixing ratio. The mixing ratio defined based on the heat release rate was shown in formula. The definition of mixing ratio was shown in equation a).

$$\text{Gasoline Mixing Ratio} = \frac{Q_{Gasoline}}{Q_{Gasoline} + Q_{DME}} \times 100\ [\%] \qquad a)$$

The COV of IMEP is below used as a measure of the limit of misfire. Note that the percentage basis standard deviation has been corrected for the heat transfer losses of a motored cycle by equation b)

$$\text{COV of IMEP}\ [\%] = 100 \times \left[\frac{Std.Dev.IMEP}{(IMEP_{fired} - IMEP_{motored})}\right] \qquad b)$$

3. Results

3.1 DME HCCI Combustion Characteristics

Fig. 3 was conducted to select the minimum required intake temperature of DME HCCI. It also shows that the starting point of combustion (CA10) was perceived, and the in-cylinder gas temperature, maximum pressure are reduced as the intake air temperature is low. Fig. 4 shows misfiring in combustion defined by in-cylinder gas maximum temperature (<1000K) and knocking defined by ringing intensity (>5MW/m2) due to temperature changes. In-cylinder gas maximum temperature was less than 1000 K at 363 K of intake temperature so that the high-temperature oxidation reaction does not occur. This means misfire. Other conditions which do not mention above there are combustion without knocking and misfiring, so that engine remain stable. Therefore, the experiment about premixed DME

3.2 DME-Gasoline HCCI Combustion Characteristics

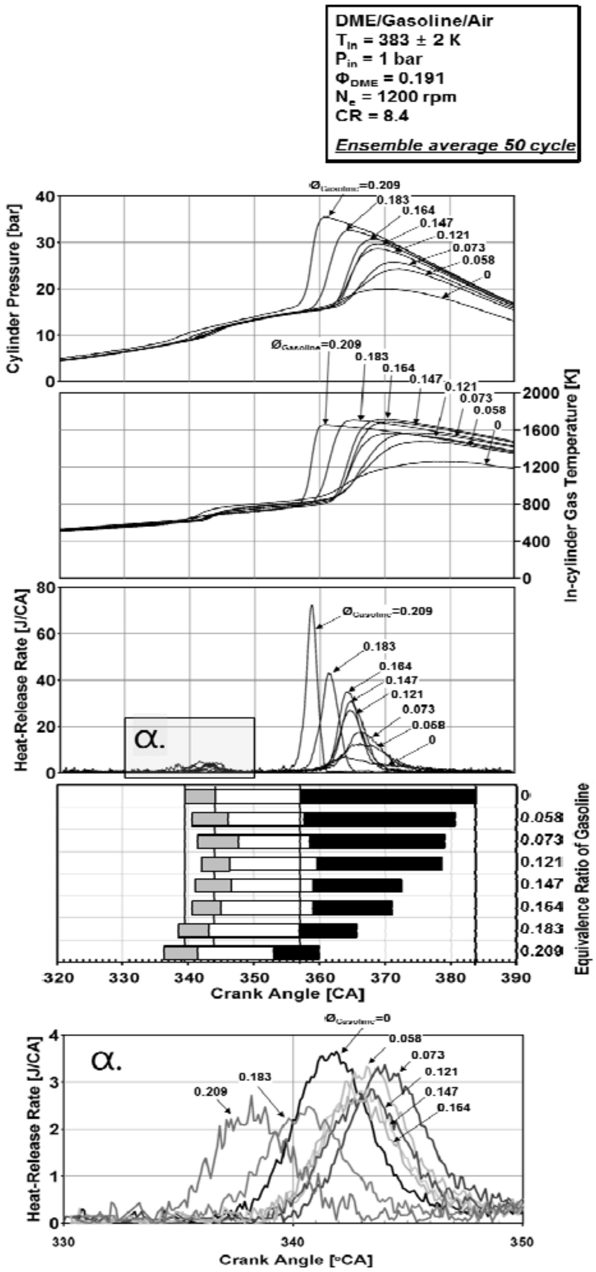

Fig. 5 DME-Gasoline HCCI combustion characteristics with various equivalence ratio of gasoline at the constant $Ø_{DME}$

Fig. 5 shows results of in-cylinder pressure, temperature and heat release rate from ØGasoline = 0 to 0.209 at ØDME = 0.191 and tendencies towards increasing in-cylinder pressure, temperature and heat release rate because of increasing input caloric value simultaneously.

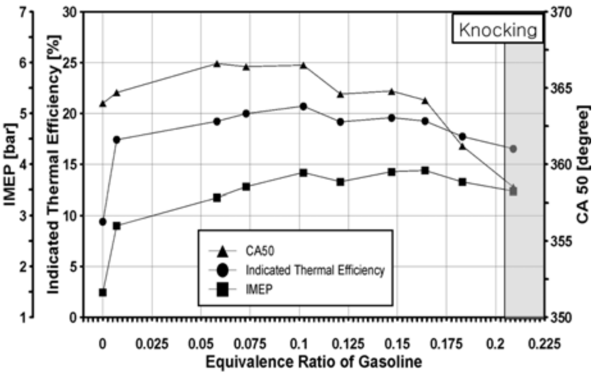

Fig. 6 IMEP, Indicated thermal efficiency, CA50 with various equivalence ratio of gasoline at the constant $\varnothing_{DME}$

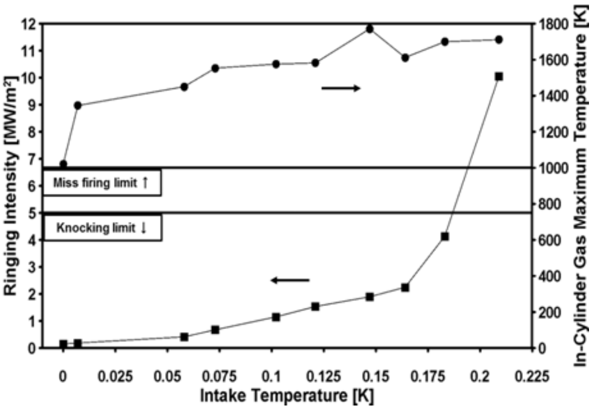

Fig. 7 Ringing intensity, In-cylinder gas maximum temperature with various equivalence ratio of gasoline at the constant $\varnothing_{DME}$

Additionally, CA10 and CA90 were not only the values of accumulated heat release rate and total of heat release rate but the points of 10% and 90% burning respectively. The combustion phasing was refer to the 50% burning point(CA50).

The CA50 was used for the basis of comparisons of combustion delay and advance. Fig. 6 shows that CA50 at Øgasoline = 0 and 0.164 were aTDC 4 degree and aTDC 6.6 respectively. As Fig. 6 shown, Thermal efficiency and IMEP were increased in the case of CA 50 delayed over aTDC 5 degree because the combustion occurred after TDC. At the conditions of Øgasoline = 0.183 and 0.209, Fig7 shows that thermal efficiency and IMEP was decreased due

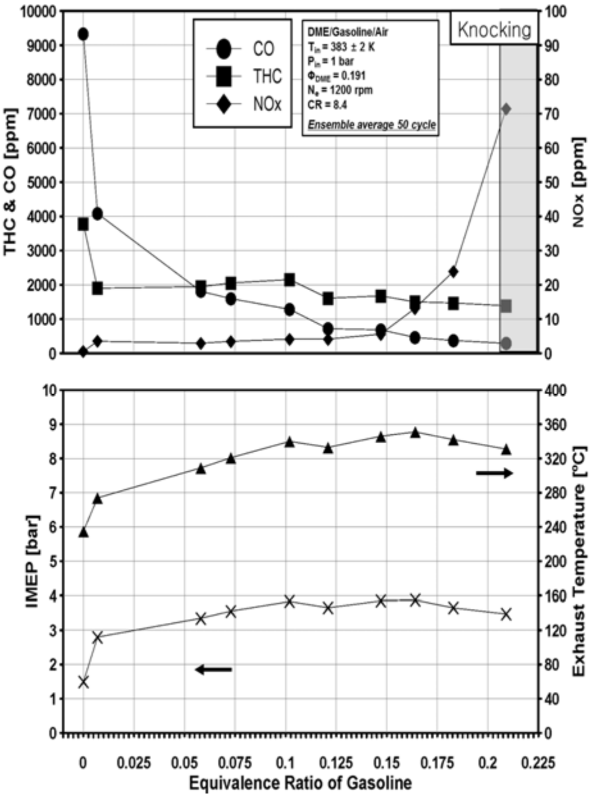

Fig. 8 DME-Gasoline HCCI exhaust characteristics with various intake temperature at the constant $\varnothing_{DME}$

to knocking from advanced CA50. At that time, ringing intensities were 4.13 and 10.05 MW/m2.

3.3 DME-Gasoline HCCI Exhaust Characteristics

Fig. 8 shows the result of the change in the amount of emissions which are THC, CO and NOx because of increasing equivalence ratio of gasoline. It shows that THC and CO were decreased, but NOx was increased simultaneously. As equivalence ratio of gasoline increases, combustion duration becomes short. The combustion duration depends on combustion temperature. This means decreased THC and CO. The reason why NOx was increased was the increase of in-cylinder gas temperature. Fig. 8 shows that Øgasoline over 0.183 which caused knocking was led to the increase of In-cylinder gas temperature rapidly. Therefore, the amount of NOx was rapidly generated.

4. Conclusion

The objectives of this paper were to research the characteristics of HCCI combustion of the DME-Gasoline mixed fuel.

1) At various equivalence ratio of gasoline, IMEP was increased by ignition delay. Because of CA50 occurred in an expansion stroke.

2) Input caloric value was increased without knocking, so that gross indicated work was increased. As a result, higher thermal efficiency was acquired than thermal efficiency of DME HCCI.

3) In-cylinder maximum temperature was over 1500K because of increasing input caloric value without knocking. It is possible reduce emissions which were THC and CO.

4) Low compression ratio engine needed more intake temperature than high compression ratio. At compression ratio 8, minimum temperature is 383K for DME HCCI.

Acknowledgement

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