

Combustion and Emission Characteristics of CNG Fuel inside CVC Chamber

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ABSTRACT

This research aims to obtain fundamentals regarding overall combustion characteristics of pre-mixed and direct injected type CNG fuel inside a constant volume chamber.

A visualization technique was introduced to a constant volume chamber in order to investigate combustion and emission characteristics of premixed and direct injected type CNG fuel inside a constant volume chamber. The experiment on a premixed combustion was conducted by measuring constant pressure and emission and controlling speeds of a swirling motor and equivalence ratios in order to investigate swirling effects on flame propagation.

Faster combustion speed and higher combustion pressure were occurred in a direct injected type combustion even under the lean condition of the equivalence ratio 0.6 compared to premixed combustion.

INTRODUCTION

CNG fuel has been an attractive automobile fuel in the view of greater fuel economy and lower emission since it is a clean fuel and abundant deposits as an alternative. In particular, since it has friendly environmental properties of superior anti-knocking, wide ranges of combustion, low unburned hydro carbon and carbon dioxide effecting green house, etc, it has become a popular alternative coping with stringent emission regulations in future [1]. In addition, presently CNG fuel has been applied to city buses and some of dirt wagons as it gives merits of outstanding lower harmful pollutants such as particulate materials compared with diesel fuel and lower engine noise and vibration. But some of task in reduction of unburned hydro-carbon and improvement of engine efficiency remains to be settled. This is due to slow response and poor precision in fuel control through

mixer or single point type injection applied to domestic natural gas vehicles currently [2-4].

In pre-mixed combustion, combustion pressure and emission by changing numbers of spark plugs and swirling effect using a fan at various equivalence ratios were measured in order to investigate combustion characteristics of natural gas. In direct injection type, appropriate injection pressures were obtained after investigating spray flow patterns and combustion characteristics by changing injection pressures under high atmosphere pressure as well. This research emphasizes on parametric study for CNG engine and aims to provide fundamental data in order to improve combustion characteristics contributing to emission reduction and performance of CNG engine furthermore.

EXPRIMENTAL EQUIPMENT & METHOD

EXPERIMENTAL EQUIPMENT

A schematic diagram of an experimental apparatus in this research is shown in Figure 1. A constant volume chamber (CVC) of bore 123mm and adjustable width 30~140mm was manufactured for the visualization of spray and combustion phenomena. CCD camera was set up around a constant volume chamber. And then, an intake valve, an exhaust valve, a pressure sensor, spark plugs for ignition and two reinforced glasses of radius 153mm and thickness 40mm for the visualization of combustion process at both sides were installed. The gases remained in a combustion chamber removed using a vacuum pump and a reducing pressure tank. A constant volume chamber was designed to modify several experimental conditions including a swirl motor, configuration of combustion chamber and location of spark plugs inapplicable to an actual engine test. In Figure 2, a swirl motor was located to investigate combustion characteristics by swirling effect.

After completion of combustion, Horiba portable gas analyzer (MEXA-554JKNOX) was used to analyze pollutants as shown in Table 1. The test was done four times under the same conditions. The experimental conditions for pre-mixed and direct injection are summarized in Table 2 and Table 3. Data of combustion pressure were obtained by DAQ(Data Acquisition: DAQ Card-6024E) based on Labview technology and all signals of CNG ignition and photographing timing were controlled using Code Vision AVR C language.

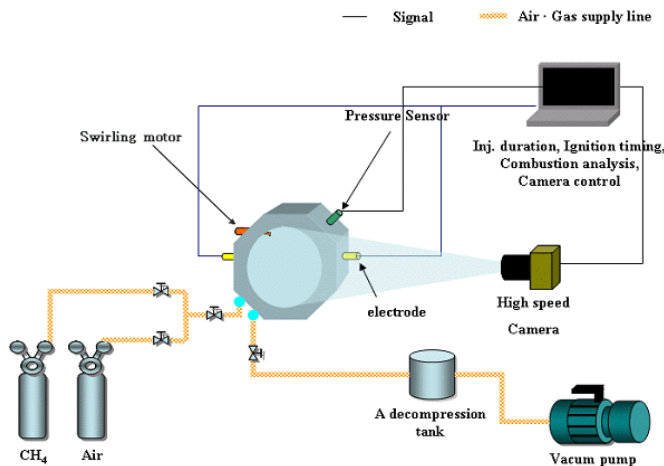


Fig. 1 Schematic diagram of experimental apparatus

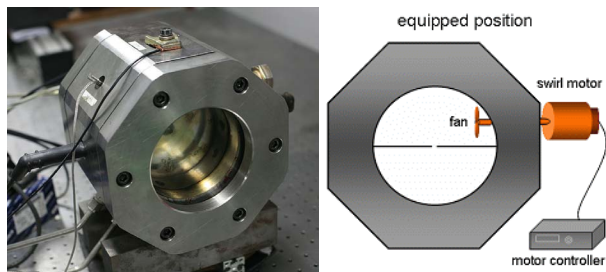


Fig. 2 Constant volume chamber and the position of swirling motor

Table 1 Gas analyzer (Horiba)

Exhaust gas	Methods
HC	NDIR
CO, CO ₂	NDIR
NO _x	CLD

EXPERIMENTAL METHOD

In CNG pre-mixed experiment, temperatures inside of combustor was maintained at 298K and the equivalence ratio was adjusted by partial pressures of natural gas and air with respect to a pressure of inside a combustion

chamber. CNG gas and air were pre-mixed inside a CVC and then ignited by spark plugs (tungsten, 1mm) to visualize phenomena of developing flame. A high speed digital camera was used to photograph and its speed was set up to 2000fps and 8000fps. And also heat-release rates from combustion process were obtained and analyzed using a piezo type pressure sensor.

In CNG direct injection, the combustion temperature was maintained to 298K and the pressure was adjusted using a compressed air and an injection pressure of injector was adjustable to 1~5MPa. After spray reach fully the location of spark, a spark plug was ignited and fired, states of the spray and developing flame were visualized.

Table 2 Experimental conditions for pre-mixed Combustions

Fuel	Natural-gas (CH ₄ 88%, C ₂ H ₆ 12%)
Ambient pressure (P _a , gauge)[MPa], Temp. (K)	1, 300
Equivalent ratio (Φ)	0.7-1.4
Swirling motor speed(RPM)	200, 600, 1000
Spark plug position	The center of CVC,

Table 3 Experimental conditions for direct injected combustions

Fuel	Natural-gas (CH ₄ 88%, C ₂ H ₆ 12%)
Inj. duration(t _i) [ms]	12 / 20
Ignition timing [ms]	ASOI* 3,6,10 / 3,10,17
Ambient pressure (P _a , gauge)[MPa], Temp. (K)	1, 300
Inj. pressure (P _i , gauge)[MPa]	1, 3, 5
Spark plug position	The center of CVC
Nozzle diameter d _N [mm]	0.6

* ASOI: After Start Of Injection

RESULT AND DISCUSSION

PRE-MIXED COMBUSTION

(1) Swirling Effect

The experiment was conducted by adjusting rotational speeds of a swirling motor in order to give swirling effects inside a CVC. Under premixed type combustion, the rotational speeds were 200, 600, and 1000rpm and a pressure inside a chamber was set to 1MPa and the equivalence ratios were adjusted to 0.8~1.2 with 0.2 interval (Figure 3-5).

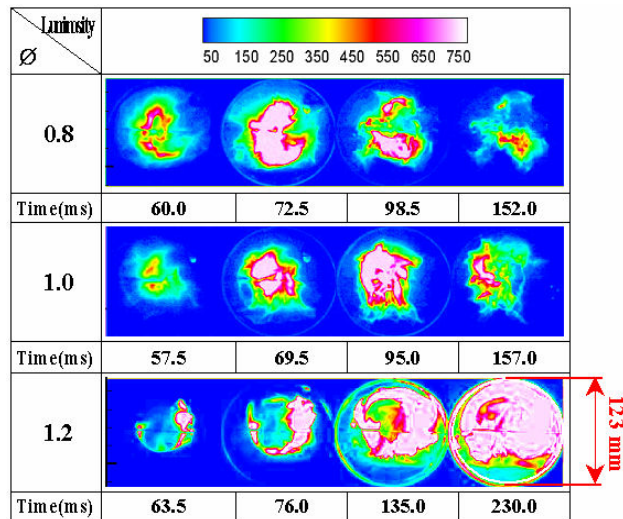


Fig. 3 Combustion images for various equivalence ratios (at a mixer or a swirling motor speed 200 rpm)

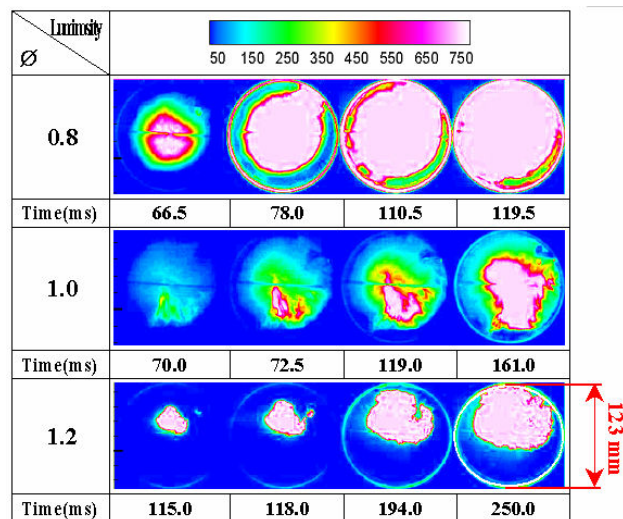


Fig. 4 Combustion images for various equivalence ratios (at a mixer or a swirling motor speed 600 rpm)

The images were obtained in order with respect to equivalence ratios when flame sizes were same as 123mm based on timing which took for flame-surface to reach a combustion chamber wall. When the motor speed is slow such as 200rpm or 600rpm, a flame was started to develop in the front of a fan. And diffusion combustion was formed as an equivalence ratio

increased and luminosity became strong. When the motor speed is faster such as 1000rpm, the conditions of pre-mixed combustion was formed because of local thick concentration area reduced by strong swirling effect.

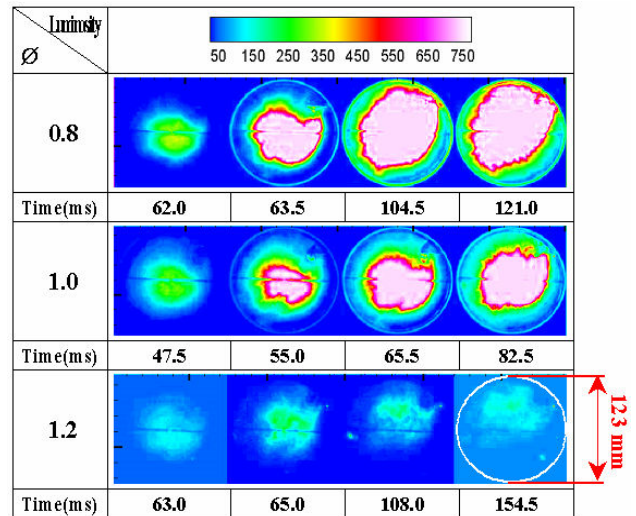


Fig. 5 Combustion images for various equivalence ratios (at a mixer or a swirling motor speed 1000 rpm)

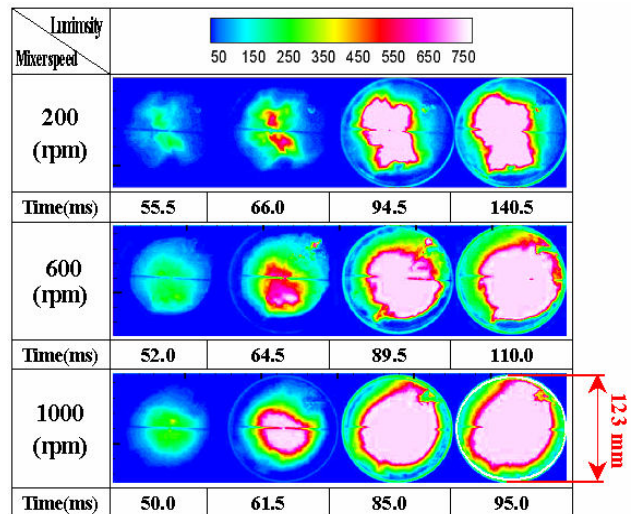


Fig. 6 Combustion images for various swirling motor speeds (at an equivalence ratio 0.9)

Figure 6 indicates the effect of rotational speeds under the condition of an ambient pressure 1MPa and equivalence 0.9. As a swirling motor speed is faster, the time taking for a flame to reach a chamber wall shorter is shorter due to swirling effect.

Figures 7-9 demonstrated combustion pressures and heat release rates with respect to times according to a swirling motor speed. As a motor speed increases to maximum combustion pressure and heat release rates