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# Characteristics of CNG Fuel Engine

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**Abstract.** In CNG vehicle, usually there are two types of fuel supply method; premixed ignition and gas-jet ignition. In premixed ignition, the fuel is introduced with intake air so that homogeneous air-fuel mixture may form. The ignitability of this method depends on the global equivalence ratio. Differently, in gas-jet ignition, CNG is introduced directly into the engine combustion chamber. The overall mixture is stratified by retarded fuel injection (close to ignition timing). This method relies on local combustible mixture near the ignition position, resulting in high ignitability.

In this study, a visualization technique is employed to obtain fundamental properties regarding overall mixture formation and combustion characteristics of direct injected CNG fuel inside a constant volume chamber and engine. For gas-jet visualization, Schlieren high speed imaging is used with the effects of ambient pressure and impingement wall on mixture formation being investigated.

**Key Words**: CNG(Compressed Natural Gas), CVC(Constant Volume Chamber), DI(Direct Injection), Visualization, Schlieren Method

## 1 Introduction

With a sharp increase of automobile demands in developing countries and a close-to-sole dependency on crude oil based internal combustion (IC) engine fuels, significant petroleum resources have been consumed and this increased consumption of the fossil based fuels has caused the environmental issues of global warming more seriously than ever before. As a result, great needs for highly efficient engines to reduce the amount of fuel consumption and eco-friendly engines to alleviate the greenhouse gas emissions easing the progression of the global warming mechanism are growing tremendously. Until at least 2020, the penetration of alternative fuels in the transportations market will rise significantly due to increasingly stringent emission standards especially for Greenhouse Gases [1]. In an effort to address this seemingly conflicting task, numerous researches with various approaches have been conducted to suggest possible solutions to the issues. Compressed Natural Gas (CNG)

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is a good candidate to limit $CO_2$ emissions, because it contains less carbon than other fossil fuels such as gasoline and diesel. The theoretical $CO_2$ emissions using CNG for the same energy introduced in the combustion chamber are 23% lower than those using gasoline in stoichiometric conditions. This is due to CNG's higher H/C (hydrogen over carbon ratio) molecular ratio: close to 4 as compared to approximately 1.8 for gasoline [2].

At present there are two types of combustion method for CNG engines; premixed ignition and gas-jet ignition. In premixed ignition, the fuel is introduced with intake air so that homogeneous air-fuel mixture may form. The ignitability of this method depends on the global equivalence ratio. Differently, in gas-jet ignition, CNG is introduced directly into the engine combustion chamber. The overall mixture is stratified by retarded fuel injection (close to ignition timing). This method relies on local combustible mixture near the ignition position, resulting in high ignitability [3].

## 2 Experimental Apparatus and Procedure

A constant volume chamber (CVC) with a bore of 96 mm and a width of 39 mm was used to visualize the jet patterns of the CNG from an injector and to analyze the diffusive flame propagations, combustion and emission characteristics. Further details of the experimental conditions are summarized in Table 1.

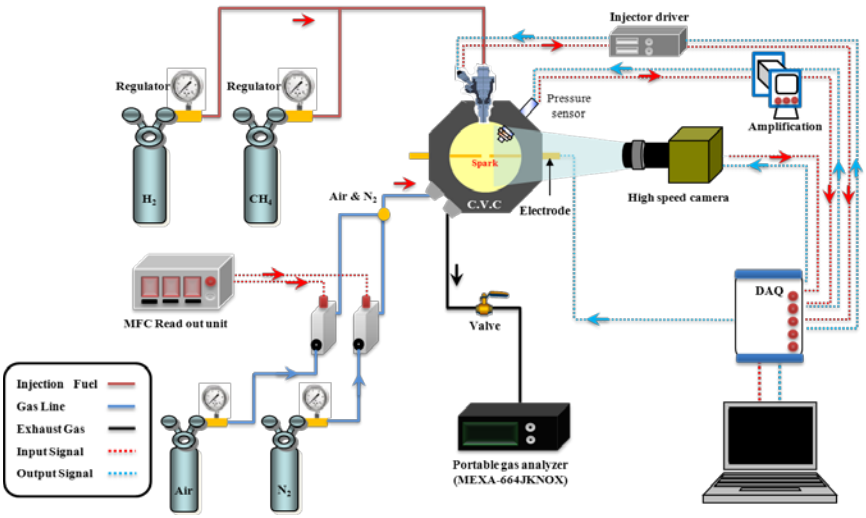


**Fig. 1** Schematic diagram of experimental apparatus with a constant volume chamber

**Table 1.** Experimental conditions

| | |
|---|---|
| CVC (mm) | 96 × 39 (Bore × Width) |
| Volume ($cm^3$) | 282 |
| Fuel Delivery | Direct injection |
| Injection pressure (bar) | 85 |
| Injection duration (ms) | 2.0 ~ 4.5 |
| Injector | 0.19 mm, 6 hole |
| Fuels (vol.%) | CNG ($CH_4$≥90%) |
| $P_{ambient}$ | Atmospheric condition<br>5 bar ($P_{inj}/P_a$=14.3)<br>10bar ($P_{inj}/P_a$=7.8) |
| $T_{ambient}$ | 20℃ |

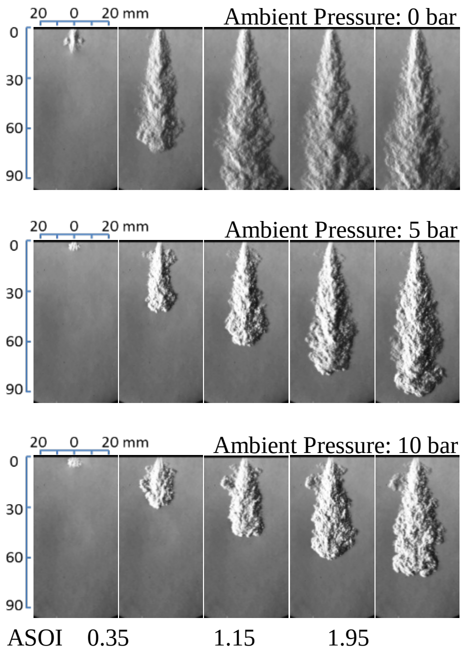


**Fig. 2** Schlieren images of the transient CNG free jet under different ambient pressure

## 3 Results and Discussion

Figure 2 shows Schlieren images of the transient CNG free jet under different ambient pressure ranging from 0.0~10 bar (gauge) with the injection pressure of 85 bar. Series of photographs were captured in time order from the beginning of injection signal. Based on the qualitative observation of these images, the penetration decreases apparently and the time reaching the CVC wall was delayed as the chamber pressure increases. This is caused by the higher inertia of the fluid elements that the injected fluid must accelerate and push aside [13]. It is same to liquid fuel such as diesel and gasoline, but this phenomenon is far more prominent for the gaseous fuel.

## 4 Conclusion

A major challenge for a direct injection engine is the optimization of mixture formation. The jet patterns and combustion characteristics of CNG fuel was investigated in a constant volume chamber. Schlieren images of CNG free jet are captured under different ambient pressures with injection pressure 85 bar. Jet formations such as its axial and radial penetration distance, tip velocity in terms of time are secured quantitatively. CNG free jet angles with respect to ambient pressure are obtained as well.

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