Effects of Various Densities and Velocities to Gaseous Hydrocarbon Fuel on Near Nozzle Flow Field in Laminar Coflow Diffusion Flames

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ABSTRACT

The experimental study on flow characteristic in various laminar coflow diffusion flame has been conducted with a particular focus on the buoyancy force exerted from gaseous hydrocarbon fuels. Methane (CH_4), Ethylene (C_2H_4) and n-Butane (C_4H_{10}) were used as fuels. Coflow burner and Schlieren technique were used to observe the fuel flow field near nozzle exit and flow characteristics in flames. The result showed that the vortices in n-Butane with density heavier than air were appeared near the nozzle exit with the strong negative buoyancy on the fuel stream. As Reynolds number increases by the control of velocity, the vortices were greater and the vortices tips were moved up from the nozzle exit. In addition, it can be found that the heated nozzle can affect to the flow fields of fuel stream near the nozzle exit.

Key Words : Laminar diffusion flame, Recirculation zone, Reynolds number, Buoyancy

1. Introduction

Laminar coflow diffusion flames have been investigated for the study of hydrodynamic structure of various hydrocarbon fuels, taking into considers the different densities of hydrocarbon [1]. Dynamic structure of buoyant jet on diffusion flame, heavy fuel density and volumetric expansion were affected on the vortex structures [2, 3]. In case of heavier fuels with densities than air, recirculation zone were appeared near the nozzle exit [4]. According to the reference, buoyancy of diffusion flame could effect to the burnt gas region. Varying Reynolds number effect to flame bulge region and complex vortex effect near nozzle exit were also investigated. We have investigated the flow field near nozzle exit and flame structure with different fuel density by coflow with air. Heated nozzle effect to flow field of near nozzle exit is also investigated [5]. In this experiment, we investigated hydrodynamic structure of normal coflow diffusion flame with different fuel types and various fuel densities. Schlieren technique was utilized to observe the flow field in diffusion flames. In particular, we focused on the vortex zones in different laminar flow flames.

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2. Experimental setup

Fig. 1 shows schematics of coflow burner setup in the experiment setup. A coflow burner was used in the experiment. The coflow air was passed through the small glass beads and go through the ceramic honeycomb again to make uniform air flow. Methane, Ethylene and n-Butane (purity > 99.5%) were selected as the fuel gaseous. Fuel velocities were 4.45 cm/s for Methane, 2.21 cm/s for Ethylene. In case of n-Butane, fuel velocities vary from 0.54 cm/s to 1.52 cm/s. For flame structure and observation of flow field in the flame near the nozzle exit, the Schlieren system was adopted. Mass flow controllers were used to control flow rate of hydrocarbon fuel and air.

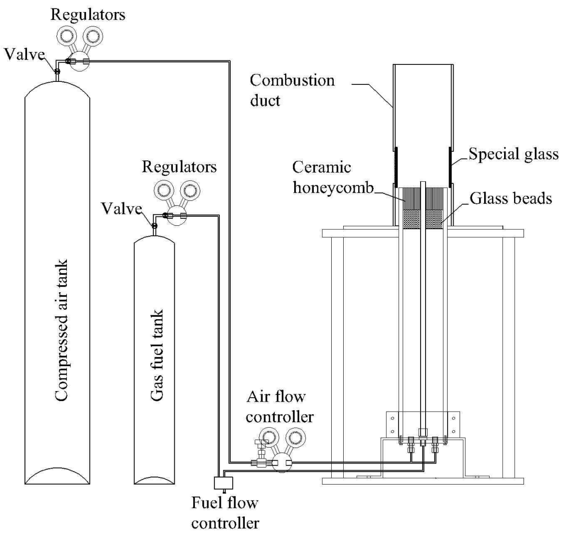

Fig. 1 Schematic of coflow burner setup

3. Results and discussion

3.1 Flame structure

Fig. 2 shows the direct flame image for different fuel. Velocities for Methane, Ethylene and n-Butane were 4.43, 2.23 and 1.09 cm/s respectively. The different velocity was selected to keep same flame height as taken on **Fig. 2.** Coflow air was supplied with velocity of 6.16 cm/s and 300K. The velocity of air makes flame in steady state. In particular, the difference in the brightness is due to sooting characteristic.

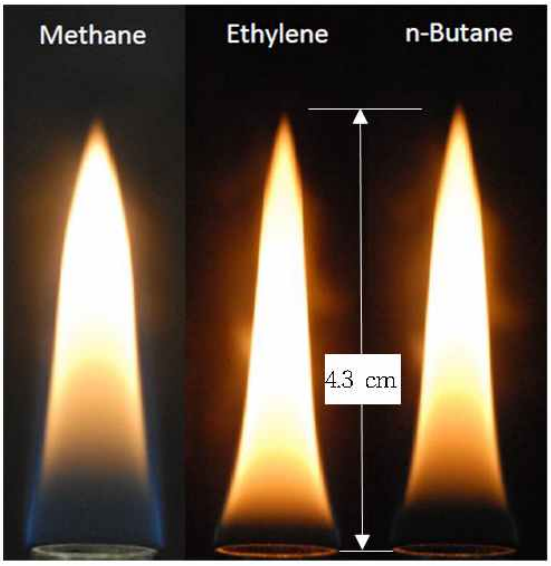

Fig. 2 Direct flame image for different kind of gaseous fuel

Methane has less sooting compared with Ethylene and n-Butane. For the Methane flame structure, the blue zone was higher than Ethylene and n-Butane flames. Ethylene luminous zone was longer than Methane flame and n-Butane flame due to the fuel-specific sooting characteristics.

3.2 Effect of heated nozzle to flow field of nozzle exit

The study investigated the effect of the heated nozzle to the fuel velocity near the nozzle exit in coflow diffusion flames. The nozzle absorbs the heat from the flame and transfers the heat to the fuel stream.

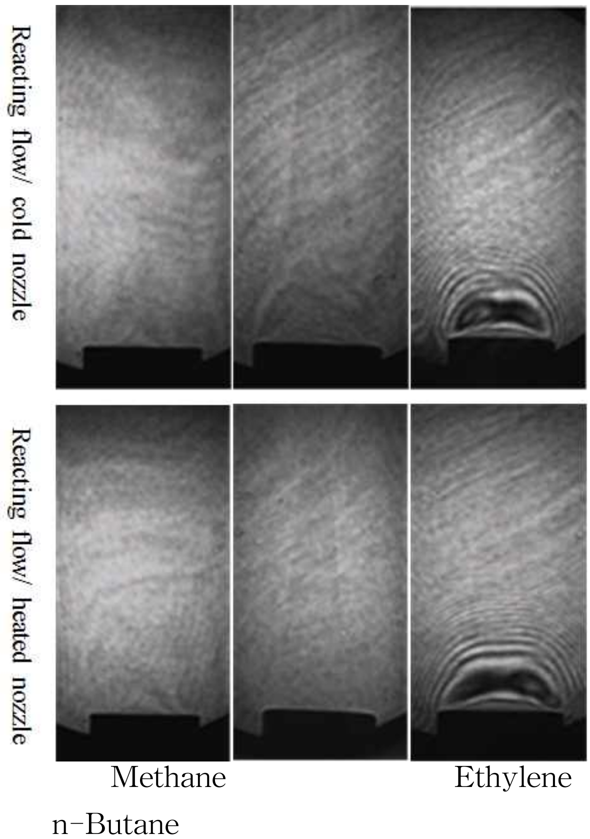

Fig. 3 Visualization of flow-field with Schlieren image for different kind of fuels

The velocity of fuel stream was increased at nozzle exit due to the heated nozzle. The reacting flow / heated nozzle with the Methane, Ethylene and n-Butane flame can be seen in **Fig. 3.** The reacting flow/ heated nozzle with n-Butane flame shows that the recirculation zone was greater than case of reacting flow/ cold nozzle due to fuel velocity increased by reacting with heated nozzle.

4. Conclusion

Flow characteristics in Methane, Ethylene and n-Butane coflow diffusion flame have been experimentally investigated, The results can be summarized as follows;

1. The density of n-Butane is heavier than air. The vortices were appeared near the nozzle exit with the strong negative buoyancy on the fuel stream.
2. Heated nozzle can affect the flow fields of fuel stream near the nozzle exit. The nozzle temperature was varied with fuel type and nozzle material.

Reference

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