報告番号	甲　第 11447 号

主 論 文 の 要 旨

論文題目　COMBUSTION CHARACTERISTICS OF HYDROCARBON DIFFUSION FLAMES WITH ADDITION OF HYDROGEN AND OXYGEN
(水素及び酸素添加を伴う炭化水素火炎の燃焼特性に関する研究)

氏　　名　呉　龍

論 文 内 容 の 要 旨

World economy development and human living has caused a sharp increase in the use of fossil fuels. Meanwhile, the use of fossil fuel produces a great number of pollutants, such as CO, CO_2 and soot et al. However, the fossil fuel in the Earth is limited and nearing depletion. Searching for alternative energy resource, improving energy efficiency and reducing pollutant emission are important subjects. In the present study, the effects of addition of hydrogen and oxygen on combustion characteristics of hydrocarbon flame inside laboratory-scale furnace were investigated via experimental and numerical methods.

Firstly, the effect of adding hydrogen to methane on the emission and heat transfer characteristics of a laminar diffusion flame was experimentally investigated. The total input thermal energy for each test was kept constant. The results showed that adding hydrogen increased the temperature, decreased the flame length, and significantly increased the soot-free length fraction. CO and CO_2 emission decreased with the addition of hydrogen. The more efficient oxidation of CO to CO_2 at higher hydrogen fractions was the main contributor to the reduction of CO, whereas decreased carbon input was the dominant factor for the reduction of CO_2. The NO_x emission increased owing to the increase of prompt, thermal NO_x formation and NNH pathway. The ratio of radiative heat flux to total heat flux decreased, and the radiative heat flux did not exceed 5% of the total heat flux. The addition of hydrogen improved the total heat flux by approximately 20%.

To understand how the added H_2 in the CH_4 stream affects the thermal characteristics of laminar diffusion flame, the kinetic effects of hydrogen addition on the thermal characteristics of laminar methane diffusion flames were numerically investigated. The results showed that the increased flame temperature with hydrogen addition can be due to the increased global heat release rate. Adding hydrogen increased the global heat release due to the increased heat contributions of reactions of $H + O_2 + H_2O \Leftrightarrow HO_2 + H_2O$, $H + HO_2 \Leftrightarrow OH + OH$, $H + CH_3 (+ M) \Leftrightarrow CH_4 (+ M)$ and $OH + H_2 \Leftrightarrow H + H_2O$, which related to the consumption of OH and H radicals. Moreover, the reaction of $OH + H_2 \Leftrightarrow H + H_2O$ is the most heavily affected by H_2 addition.

The effects of hydrogen addition on the emission and heat transfer characteristics of oxygen-enriched laminar methane diffusion flames were also experimentally investigated in a laboratory-scale furnace with a co-axial burner. The volume fraction of hydrogen in the methane-hydrogen blend was varied from 0% to 50%, and the oxygen concentration was varied from 25% to 35%. Results showed that the addition of hydrogen led to an increase in the soot-free length and flame temperature while the degree of increase was less at higher oxygen concentrations. Adding hydrogen chemically enhanced the oxidation of CO to CO_2, and this chemical effect was stronger when the oxygen concentration increased. NO_x emissions increased significantly with the addition of hydrogen, while the rate of this increase decreased with greater oxygen concentrations. The total heat flux increased with the addition of hydrogen, while the rate of this increase was less at higher oxygen concentrations. Although the radiative heat flux increased with higher oxygen concentrations, it did not exceed 6% of the total heat flux at 35% O_2. Moreover, adding hydrogen decreased the radiative heat flux; this decrease was significant at higher oxygen concentrations.

Finally, the effects of oxygen concentration and fuel (methane and propane) jet velocity on thermal radiation in turbulent diffusion flames were investigated by numerical simulation, using a detailed gas-phase reaction mechanism consisting of 36 species and 219 elementary reactions with the discrete ordinates method. The predictions show close agreement with the experimental results in literature. Especially, the radiative heat transfer flux and radiation fraction of propane flames were larger than those of methane flames at the same input power because of the increased soot yield in propane flames. In both methane and propane flames, thermal radiation generally increased with oxygen concentration, while at higher oxygen concentrations the degree of radiation increase was lower. Because of the promotion of soot oxidation at higher fuel velocities, the radiant fractions were lower than at lower fuel velocities.