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The effect of residence time and flame temperature on the soot formation of a liquid fuel flame

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Soot emission from the fossil fuel combustion causes many environmental problems and its reduction is one of the most important topics in combustion research. Until now, soot formation of gaseous fuels have been investigated and successfully modeled in many studies. However, soot formation mechanisms of liquid fuels are not fully understood yet. The soot formation mechanism of the liquid fuel is more complex than that of the gaseous fuel because there are vaporization process and interaction between the fuel droplet and flame in the liquid fuel flame.

Generally, the soot yield for each fuel at and above threshold is uniquely determined by the flame temperature in the sooting region, regardless of how this temperature was achieved [1]. The residence time of the soot particle in the high temperature region is also very important to the soot formation and there is an inception limit that the residence time is too short to initiate the formation of soot particles [2].

In the previous work, Kennedy [3] numerically simulated the dynamics of soot aerosol in a stagnation point diffusion flame numerically and reported the influence of the residence time on soot loading. Bossard showed that the initial droplet-size distribution can have a direct influence on the burning characteristics of poly disperse fuel sprays. Regarding to the flame temperature, Beltrame et al. [5] studied the soot and NO formation in the methane-oxygen enriched diffusion flame. They measured the soot volume fraction in terms of the flame temperature and strain rate variation. They also reported that the NO concentration varies with respect to the temperature reduction due to the radiative heat loss results from soot particles.

In this study, we investigated the effect of residence time and flame temperature on soot formation and its growth rate of liquid fuel flame in the counter-flow configuration. We introduced the liquid fuel to the methane-air flame and measured the flame temperature and soot volume fraction with various experimental conditions. The aim of this research is to gain more information about the parameter affecting on the formation and growth of soot particles from fuel droplets. We changed the flame temperature by diluting the fuel and oxidizer, and varied the residence time by changing the strain rate. We measured velocity gradient, flame temperature and soot volume fraction by using laser Doppler anemometry (LDA), thermo couples and Rayleigh scattering method, and laser induced incandescence (LII), respectively [6,7,8]. The LII signal is calibrated by using the laser extinction method.

The results of this study help explaining the interaction between the fuel droplet and flame, and they also show the detailed process of soot formation form the fuel droplet. These results can be used as basic data in the modeling of various combustion devices which use the spray combustion.

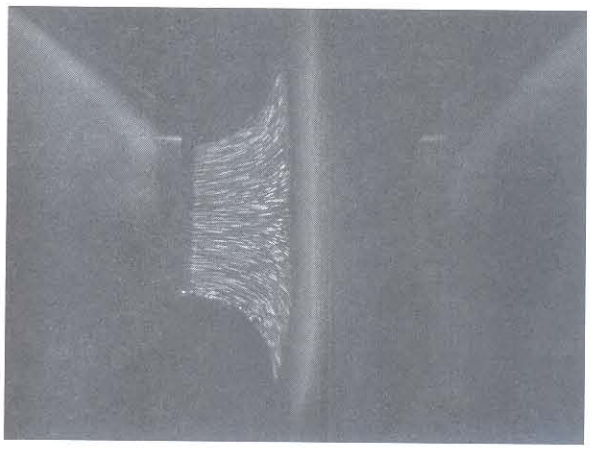

Fig. 1 The direct photo showing the interaction between the liquid fuel and methane flame.

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