The effects of hydrogenation on the shape and fluctuation of lean methane flames formed on a flat burner

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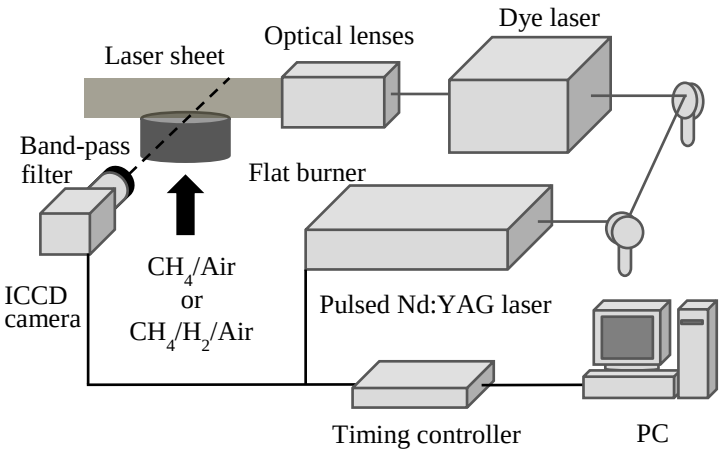
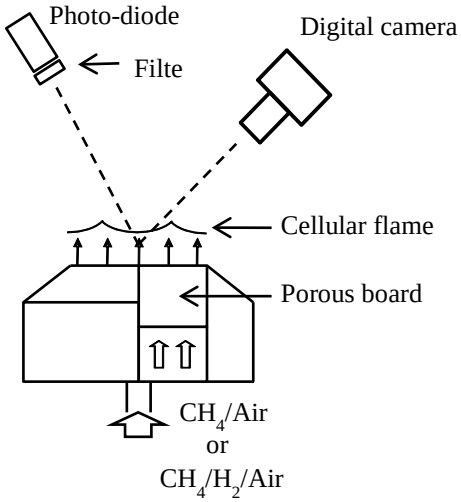
We treated lean combustion system of CH_4 / H_2 / Air mixtures to reduce emissions of carbon dioxide and nitrogen oxide and to extend flammable range. We studied the effects of hydrogenation to lean methane-air mixtures on the shape and fluctuation of cellular flames formed on a flat burner. Cellular flames were directly photographed to obtain the average size of cells, and the planar laser-induced fluorescence of CH radicals (CH-PLIF) was used to obtain the average cell depth, i.e. the front shape of cellular flames. In addition, the light emission from premixed flames was measured to reconstruct an attractor through the time series analysis. The measured intensity of light emission was normalized by its average value, and the normalized intensity varying with time was used in the time series analysis. Adopting Taken's embedding theorem, we reconstructed an attractor, where the embedding dimension was set to three and the time delay was assumed to be the fourth of the typical frequency. The typical frequency which had peak value of power spectrum was obtained from FFT analysis. Scrutinizing the reconstructed attractor, we elucidated the characteristics of unstable behavior of cellular premixed flames.

As the equivalence ratio became lower, both of the average cell size and cell depth increased, which was because of the diffusive-thermal effects. The reconstructed attractor had a doughnut shape, i.e. torus structure, indicating that the fluctuation of cellular premixed flames was quasi-periodic. Lower the equivalence ratio, larger the reconstructed attractor. Compared with CH_4 / Air mixtures, cellular fronts were observed at low equivalence ratios, and the trajectory of attractors was complicated. The former denoted the extension of flammable range, and the latter indicated the increase of instability intensity resulting from hydrogenation.

In conclusions, we treated lean CH_4 / H_2 / Air mixtures to study the shape and fluctuation of cellular premixed flames. As the equivalence ratio became lower, the average cell size and cell depth increased, and the reconstructed attractor with torus structure became larger. In comparison with CH_4 / Air mixtures, cellular fronts were observed at low equivalence ratios, and the trajectory of attractors was complicated. The obtained results clarified the extension of flammable range and the increase of instability intensity, resulting from the hydrogenation to lean methane-air mixtures.



Experimental setup (CH-PLIF)



Experimental setup (flat burner)