学　位　論　文　内　容　の　要　旨

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学　位　論　文　題　名

Effect of Flame Deformation of Downward Propagating Flames Induced by Laser Irradiation Method on its Combustion Instability
(レーザー照射法による管内下方伝播火炎の変形が燃焼不安定性におよぼす影響)

Thermo-acoustic instabilities result from complex dynamic interactions between heat release fluctuation from flame and acoustic oscillation filed. Thermo-acoustic instabilities are often destructive to the operation of combustion systems and are major challenge in the development of lean premixed combustors with ultra-low emissions. Therefore, numerous researches have been conducted to understand the mechanisms of the thermo-acoustic instabilities. Of these, a simple experiment to generate and study thermo-acoustic instabilities is a downward-propagating flame in an open-closed tube.

Flames propagating in tubes with specific structure can spontaneously produce acoustic oscillations. A parametric instability represented by corrugated flame is transitioned from a vibrating flat flame which is subjected to a primary acoustic instability. According to a theoretical velocity coupling, the variation of flame surface area during propagation in tubes is theoretically studied to show a proportional effect to the growth rate of thermo-acoustic instabilities. This effect can be studied more precisely if flame structure is actively controlled. In previous studies, a single CO_2 laser irradiation (*SLI*) method was extensively used to artificially control the flame shape. In this thesis, a double laser irradiation (*DLI*) method is developed based on the *SLI* setup. A single or a double cellular structure is formed when a flat flame is exposed to the *SLI* or *DLI*, respectively. As a spatially sinusoidal shape is formed, the cellular structure is characterized by the amplitude of the cell (a) and wavenumber (k) as a function of wavelength, $k=2\pi/\lambda$. Consequently, at a given laminar burning velocity and using the same total laser power, different coupling parameter a and k of the cellular structures propagating under *SLI* and *DLI* would generate different thermo-acoustic responses. These responses can be comparatively examined to develop a more comprehensive criterion for the transition from primary acoustic instability to parametric instability. Hence, the structure of the laser-induced flames and their effect on the growth of acoustic pressure fluctuations are discussed to clarify the criteria of the transition from primary acoustic instability to parametric instability.

In Chapter 1, the nature and the physics of thermo-acoustic instability were briefly reviewed. In addition, the flame acoustic coupling in combustion tube were presented. Then, the objective and the scope of this study were introduced.

In Chapter 2, the experimental setup of the *SLI* and *DLI* how the laser beams are directed into the combustion tube were described. The properties and compositions of gas mixtures were specified. Then the experimental procedure to obtain the flame propagation induce by laser irradiation and acoustic pressure fluctuation was revealed.

In Chapter 3, effect of flame surface area (as a function of a and k) of downward propagating flames induced by *SLI* and *DLI* on transition from primary acoustic instability to parametric instability was clarified. The effect was revealed through an experimental comparison on the criteria of transition to parametric instability of flame when it is exposed to *SLI* and *DLI*. The distance between two beams in the *DLI* setup is fixed at 18 mm. The results showed that the growth rate of primary acoustic instability during the propagation of the deformed flame is important to enhance the pressure fluctuation amplitude that further reaches the critical value for the transition to parametric instability. Furthermore, a linear relationship was found between the area of the deformed structure (irrespective of its dimension) and the corresponding growth rate of acoustic pressure fluctuation during the propagation of the deformed flame. Using the *DLI* method, the actual flame area, rather than $(ak)^2$ as mentioned in the velocity coupling, was found to be the factor that determines the growth rate under nonhomogeneous cell distribution.

In Chapter 4, the effect of geometric deformed structures induced by *DLI* on the growth rate thermo-acoustic instability was presented. The experiments were conducted at a given laser power while the distance between the beams in the *DLI* setup is varied from 8 mm to 20 mm with interval of 4 mm. When the beam separated distance was smaller than 16 mm, individual cell was merged together, the laser-induced structures were no longer in the form of sinusoidal shape. This resulted a difference in the curvature among the non-sinusoidal and sinusoidal structure. Subsequently, the variation of curvature gave different effect that contributed to the growth rate of thermo-acoustic instability during the propagation of deformed flame. Therefore, relationship between the flame area and the growth rate of acoustic pressure fluctuation was not linear as found in the experiments discussed in the previous chapter where all the geometric structures of deformed flame are the sinusoidal form. Based on that, the contribution of curvature effect or flame stretch rate is determined.

In Chapter 5, a summary of findings in the present study and conclusions were given.