学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Research on Le effect of Acoustic Instability in Downward Propagating Flames
(下方伝播火炎での音響学的不安定性に対する Le の影響)

An interaction between a heat release and acoustic fluctuations can cause the thermoacoustic instabilities. It is important to understand the thermoacoustic instabilities because industrial applications such as rocket engines and gas turbine are often suffering from the thermo acoustic instabilities, and it leads performance degradation, in addition to shortening its lifetime.

Among the experimental studies of thermoacoustic instabilities, flame propagation experiment in a combustion tube open at one end is among the most elementary and widely employed to describe the different types of development of acoustic instability. The primary acoustic instability is evolved from a curve flame of hydrodynamic instability region to a vibrating flat flame and the secondary instability is evolved from a flat flame to the turbulent motion via a corrugated flame. The typical feature of primary acoustic instability is that the flame shape is planar. Therefore, the Lewis number effect on acoustic instability which is contributed by flame front curvature cannot be observed in general. However, the utilization of CO_2 laser irradiation facilitates the modification of flame front shape. The research on Le effect on acoustic instability was carried out through controlling flame front shape.

In Chapter 1, briefly overview of premixed flame, intrinsic flame instabilities, and acoustic instabilities in combustion tube are elucidated. Then, an objective and a scope of this study are presented.

In Chapter 2, the experimental setup and procedure are described. The combustion tube (transparent acrylic tube, 50-mm inner diameter and 711-mm length) is fixed vertically and charged with the tested gas at atmospheric pressure. The premixed gas was composed of ethylene, oxygen, carbon dioxide, and propane. Ethylene gas is mostly used as a fuel. In some cases, ethylene and propane mixture was used to keep ethylene concentration in the gas composition to attain constant laser absorption rate. The time-dependent behaviors of the downward-propagating flame are recorded by high-speed cameras. The temporal variation of the acoustic pressure is measured at the bottom end of the tube.

In Chapter 3, the main focus is to examine effect of Lewis number on the growth of acoustic pressure. The CO_2 laser irradiation method is applied to alter the shape of the flame front, resulting in obtainment of convex and concave curvature. The generation of convex curvature by laser irradiation can facilitate the growth of acoustic pressure for Le<1 because the concentration of the deficient reactant approaching the flame could be converged with the convex flame structure. When the laser power increases, the amplitude of the convex curvature of flame also increases. It means that the flame undergoes stronger thermal diffusive instability, resulting in the growth rate of acoustic pressure rise. For Le>1, the growth of acoustic pressure amplitude is suppressed while the flame has the convex curvature by laser irradiation. It can be also elucidated by the mechanism of diffusive thermal instability. In Le>1, the thermal diffusion process is more dominant and hence the defocusing effect of the

thermal diffusion is stronger than the convergence effect of deficient reactant. It causes the local flame temperature decrease and the suppression of growth of acoustic pressure.

In Chapter 4, the effect of Le on the transition from primary acoustic instability to secondary acoustic instability in nonequidiffusive flame is described. The Lewis number effect is significant on the enhancement or decline of heat release, and it also leads to two distinct transition behavior: (1) the flame transits from convex flame structure to secondary acoustic instability; (2) the flame transits from concave flame structure to secondary acoustic instability. An attempt was made to establish the stability map of the transition as a function of laser irradiation conditions. The transition criteria variation is very limited for Le<1 as a function of laser exposure time and the transition behavior is always same as (1). The transition occurs very initial moment of the period of laser irradiation because the convex curvature causes local flame temperature rise. In this scenario, the transition criteria in terms of laser exposure time cannot be sufficiently changed. Both transition behaviors were observed in Le>1 in terms of laser exposure time. In short term laser exposure cases, only convex flame front was obtained owing to shortage of laser exposure time and the transition behavior is also of (1). Therefore, the flame requires higher laser power to enable the transition due to the negative effect of Le. Once sufficient laser exposure time is given to form the concave structure, the transition begins from the concave curvature under the influence of concave flame structure.

Increasing laser power decreases the critical transition laminar burning velocities in both Le>1 and Le<1. The concave transition region in the binary fuel cases is wider than the single fuel cases. The Lewis number of binary fuel cases for fuel lean condition is larger than that of single fuel cases (1.09>1.05). It may induce easier transition for binary fuel cases. The transition criteria have very different sensitivity to the input laser power in terms of the transition modes and, even with same input laser power, the amplitude of flame front curvature is quite different between the convex and concave flames. The quantitative evaluation of curvature effect on flame burning velocity was conducted to more clarify the Lewis number effect on the transition phenomena. The result in case of concave structure is much higher than that of convex structure. It means that the effect of concave curvature is stronger than the convex curvature even under same input laser power and such relatively stronger curvature effect can cause more sensitive response of the transition criteria variation

In Chapter 5, conclusions are briefly summarized based on experimental observation.