

Combustion Control by Forced Pulsating Mixture Supply and Detection of Symptoms on Self-Excited Combustion Oscillation

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Abstract : A new idea to suppress the self-excited combustion oscillation was applied to the flames. The characteristics of unsteady combustion were examined, which is driven by forced pulsating mixture supply that can modulate its amplitude and frequency. The self-excited combustion oscillation having weaker flow velocity fluctuation intensity than that of the forced pulsating supply can be suppressed by the method. The effects of the forced pulsation amplitude and frequency on controlling self-excited combustion oscillations were also investigated comparing with the steady mixture supply. The unsteady combustion used in this experiment plays an important role in controlling self-excited combustion oscillation. In addition, Symptoms of self-excited combustion oscillation were also studied in order to predict the onset of combustion oscillation before it proceeded to a catastrophic failure. For the purpose, we have found and proposed unique measures to tell the onset of self-excited combustion oscillations based on the careful statistics of fluctuating properties in flames, such as pressure or OH chemiluminescence.

Key Words : Combustion oscillation, Unsteady combustion, Forced pulsating mixture supply, Oscillation control, Symptom of combustion oscillation

1 INTRODUCTION

In order to increase the combustion load and reduce the nitric oxide emission, the lean premixed combustion has been used as an effective combustion method. From a practical point of view, the combustion instabilities or combustion oscillations often take place and hinder performance of combustors, for example, such as boilers, gas turbines, rocket engines when the premixed combustion is used [1].

Aerodynamic oscillations can be typically classified into either Helmholtz type or longitudinal acoustic oscillation. The geometry of flow system, such as volume of combustion chamber, length of passages of reactants and exhaust, may yield countless modes of natural oscillation as the cause of combustion oscillation. Under a certain condition, if the fluctuation of heat release rate combines with one of the natural oscillation modes, self-excited combustion oscillation starts to occur by the resonance. The onset of self-excited combustion oscillation requires that the relation between pressure fluctuation and fluctuation of heat release rate in combustor must satisfy the condition called as Rayleigh's criterion. Generally, the pressure fluctuation and fluctuation of heat release rate have a phase difference. When the phase difference τ is in the range of $-\pi/2 < \tau < \pi/2$, it is known that the Rayleigh's criterion representing the onset of self-excited oscillation is satisfied.

Control methods of self-excited combustion oscillation are divided into passive control and active control. The former is performed, for example, by changing the geometry of combustors, and the latter is achieved by feedback procedure in which the phase-shifted pressure fluctuation signals of the

combustion chamber are used to modify the feed rate of the mixture [2, 3].

In order to elucidate the mechanism of self-excited combustion oscillation and to utilize the merits of self-excited combustion oscillation positively, like pulse combustors, many studies have been conducted [4-6]. In these studies, the most important measurement quantities in order to understand behaviors of combustion oscillation were the correlation between pressure fluctuation and fluctuation of heat release rate. As for the pressure fluctuation, it is measured in many cases using pressure sensor connected to combustion chamber, directly or through a connection pipe. However, it should be careful about the distortion of pressure signal within a connection pipe [7, 8]. As for the fluctuation of heat release rate, on the other hand, it is difficult to measure directly. Therefore, OH or CH radical chemiluminescence is used as an indicator of heat release rate [8-10].

In the present study, the effects of forced pulsating mixture supply performing continuous combustion that could reduce the intolerable combustion noise of pulse combustion as well as promote the merits of pulse combustor were studied. From this viewpoint, the combustion system using the characteristics of unsteady flow or forced pulsating mixture supply is hardly found in the past. The characteristics of combustion behavior were investigated in a duct-combustor with a rearward-facing step by applying unsteady combustion driven by a forced pulsating mixture supply of propane-air mixture. It was confirmed that the forced pulsating mixture supply was useful to control the self-excited combustion oscillation by investigating its influence on the onset of self-excited combustion oscillations.