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Effects of operating pressure on flame oscillation and emission characteristics in a partially premixed swirl combustor

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ABSTRACT

The influence of varying combustor pressure on flame oscillation and emission characteristics in the partially premixed turbulent flame were investigated. In order to investigate combustion characteristics in the partially premixed turbulent flame, the combustor pressure was controlled in the range of −30 to 30 kPa for each equivalence ratio (Φ = 0.8–1.2). The r.m.s. of the pressure fluctuations increased with decreasing combustor pressure for the lean condition. The combustor pressure had a sizeable influence on combustion oscillation, whose dominant frequency varied with the combustor pressure. Combustion instabilities could be controlled by increasing the turbulent intensity of the unburned mixture under the lean condition. An unstable flame was caused by incomplete combustion; hence, EICO greatly increased. Furthermore, $EINO_x$ simply reduced with decreasing combustor pressure at a rate of 0.035 g/10 kPa. The possibility of combustion control on the combusting mode and exhaust gas emission was demonstrated.
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1. Introduction

Combustion instability has a strong influence on combustion efficiency and pollutant emissions. In various industrial applications, these instabilities also cause many problems, such as system damage, flame extinction, and NO_x emission. Therefore, methods are required to control the flame instability. Combustion instabilities are affected by feedback interaction between the natural acoustic mode of the combustor and the oscillation of the heat-release rate [1,2]. For controlling combustion instability, many research groups have developed various combustion control technologies, such as air–fuel-ratio oscillations at the combustor inlet, mixing-rate fluctuations between the burned and unburned mixtures, imposition of oscillations, injection of secondary fuel, and so on [3–7]. Venkataraman et al. [3] performed experimental studies of the mechanism of unstable in a coaxial bluff-body stabilized dump combustor. They considered equivalence ratio, inlet velocity, inlet fuel distribution and swirl regarding combustion instability. They investigated the relationship between the mean reaction rate and the local flame structure during combustion instability in a swirl-stabilized combustor [4]. The effect of the injection position of primary dilution air has been studied in a swirl-stabilized combustor [5]. It is observed that primary dilution decrease flame size, and has an effect on the flame structure, on local combustion equivalence ratio, which induces effects on flame stability and on CO emission. Lee et al. [6] demonstrated closed-loop active instability control in a laboratory-scale swirl-stabilized combustor using subharmonic modulation of secondary fuel injection. They found that the combustor inlet fuel distribution could have a significant effect on flame stability as well as changes in the flame structure and heat release distribution. Combustion instability in a swirl-stabilized combustor based on fuel flow modulation was also reported by Choi et al. [7]. They found that pressure fluctuation can be controlled by secondary injection, and this control is effective on suppression of combustion oscillation, prevention of lean blowout, and reduction of emission index.

The combustor pressure has a significant effect on flame stabilization and emission characteristics even if the pressure change is several tens of Torr. It is generally well known that the combustor pressure influences the flame shape, burning velocity, combusting mode, and nitric oxide emission. Many researchers have investigated the influence of the combustor pressure on combustion characteristics. Liakos et al. [8] analyzed the mechanisms that control the premixed combustion phenomenon under various pressures (atmospheric and higher pressures) and investigated the effects of elevated pressure on the turbulence characteristics. It has been predicted that the size of the combustion zone was reduced as the reactant pressure increases. More recently, a comparison between experiments and theory on turbulent premixed flames under high-pressure conditions has been conducted by Soika et al. [9]. They studied flame structures and turbulent characteristics

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