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浮き上がり高さのD.C.シフトが定在音場でのTriple FlameのPOD解析に与える影響

Influences of D.C. Shift in Lift-off Height on POD Analysis of Triple Flame in Standing Acoustic Field

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Abstract: In order to investigate influences of D.C. shift in lift-off height on oscillation mode of triple flame in standing acoustic field, POD analysis was conducted on simulated images with D.C. shift in the lift-off height. The chemiluminescence of acetone doped methane/air flow was excited by PLIF (Planar Laser Induced Fluorescence) to capture the shape of the triple flame cross section. The triple flame was formed in a mixing layer between fuel and air by using a multi-slot burner. A monotone standing acoustic wave whose frequency of 441Hz is formed in a stainless resonance tube in consideration of the resonance frequency and the phase difference with the laser used for the PLIF. As a result, it is clarified that the unexplained mode in previous study appears when transverse oscillation in *x*-axis direction and D.C. shift in the lift-off height are combined.

１．Introduction

In combustors with anchoring flames, such as jet engines, non-uniform mixing of fuel and oxidizer causes fuel concentration gradient, resulting in the formation of a flame called “triple flame”[1]. Combustion oscillation may occur in this type of combustor, leading to the distruction of the combustor. Rayleigh’s criterion, which is determined by the phase difference of pressure and heat generation fluctuations, is proposed as condition for the occurrence of combustion oscillations[2]. Therefore, it is important to predict the fluctuation and location of heat generation by a flame. Saito et al. modeled the meandering upstream mixing layer[3]. This model shows that the fuel concentration gradient fluctuates periodically and the flame moves due to variation of the mixing layer width. Hamano et al. conducted a POD analysis on cross-sectional images of triple flame in standing acoustic field obtained by acetone PLIF[4]. As a result, an oscillation mode that can not be expected from Saito’s model was found. In the time variation of the unexpected oscillation mode, D.C. shift in the lift-off height was dominant.

In this study, influences of D.C. shift in the lift-off height on the oscillation mode analysis of triple flame in standing acoustic field were investigated by the POD analysis taking account of the lift-off height change.

２．Experimental setup and procedure

２．１　Experimental equipment and conditions

Experiments were conducted using a multi-slot burner with four rectangular slots of measuring 10 mm × 60 mm. Fuel/air mixture flows from one of the two inner slots and air flows from the other one to form a mainflow. To reduce the effect of vortices caused by the shear between the mainflow and the ambient air, nitrogen is injected through the two outer slots at the same velocity as the mainflow.

Table 1. Experimental conditions.

Mixture gas	CH_4/Air
Equivalent ratio [-]	3.0
Concentration of acetone [vol.%]	7
Flow velocity U [m/s]	1.0
Resonance frequency f [Hz]	441
Sound pressure [kPa]	0.20

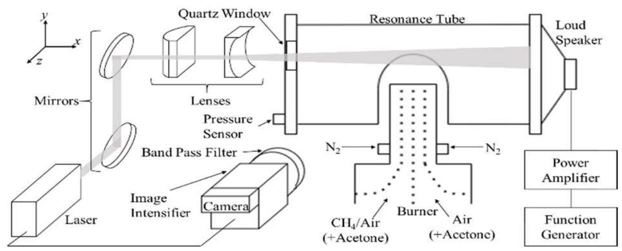

Figure 1. Schematic of the experimental apparatus.

The frequency of the applied acoustic oscillation was adjusted to keep the resonance. The laser sheet was irradiated into the resonance tube through a quartz window attached to an end wall. The laser wavelength is 266 nm. The acetone fluorescence was captured at 10 fps, which is the a laser repetition rate. The peak of the fluorescence spectrum is 480 nm[5]. A band-pass filter with a central wavelength of 480 nm (FWHM: 10 nm) was attached to the lens to omit all fluorescence except that of acetone. To reduce the effect of

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the flame chemiluminescence emission, exposure time was set to 0.15 μs before and after the flourescence of acetone. The 800 images which corresponds with 80 cycles were taken.

２．２　Oscillation modes and D.C. shift in the lift-off height

Snapshot POD, which is used to detect the characteristics of a flow field, was conducted to analyze the flame oscillations. As shown in Figure 2, oscillation mode of triple flame is expected to have transverse oscillation in both *x*-axis and *y*-axis directions and vibration in flame curvature. However, any of expected modes from Saito's model does not match with POM3 (enclosed in orange), which is found in previous study. Also, D.C. shift in the lift-off height was dominant in the POM3.

An animation was reconstructed to simulate oscillation modes of triple flame. Characteristics of movements in triple flame used were data of Topos and Chronos which is a transverse oscillation in *x*-axis direction and D.C. shift in the lift-off height. An approximate in red shown in Figure 3 was used to simulate D.C. shift in the lift-off height.

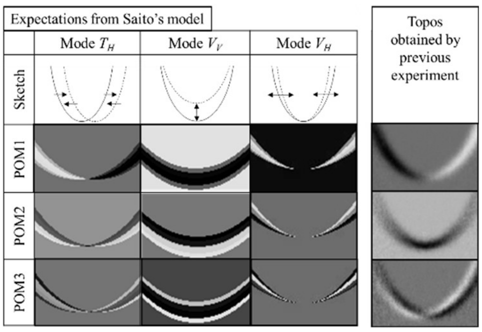

Figure 2. Expectations and previous study of Topos and frequency corresponding to the oscillation mode[4].

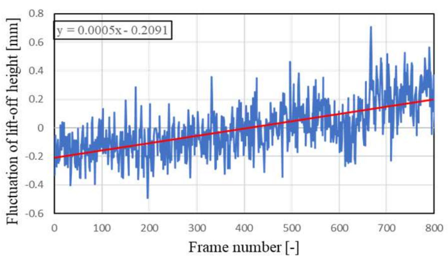

Figure 3. History of the flame anchoring position[4].

３．Results and discussion

The result of POD analysis for previous study and the animation which is reconstructed by adding D.C. shift in the lift-off height to transverse oscillation in *x*-axis direction, is shown in Figure 4 and Figure 5. Since the color scheme of Topos and the phase plane of Chronos are equal to those of the previous study, experimental result was reproduced by taking D.C. shift in the lift-off height into account. Therefore, it is clarified that POM3 in previous study appears when transverse oscillation in *x*-axis direction and D.C. shift in the lift-off height are combined.

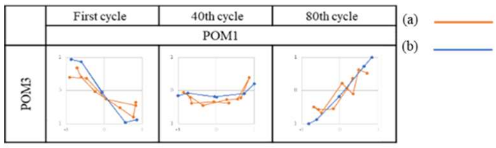

Figure 4. Normalized Chronos of POM3.
(a) previous study[4], (b) reconstructed animation

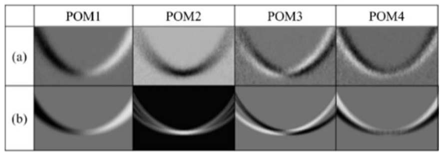

Figure 5. Topos of each mode.
(a) previous study[4], (b) reconstructed animation

４．Conclusion

By taking account D.C. shift in the lift-off height, it is clarified that the unexplained mode in previous study appears when transverse oscillation in *x*-axis direction and D.C. shift in the lift-off height are combined.

５．Acknowledgements

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