Background

Gas turbine engines are widely used in aircraft, marine, and electrical power generation systems for clean, efficient power source. These machines are capable of combined cycles efficiencies up to 60%.

Emission reduction strategies for power generation gas turbines utilize lean combustion where combustion instabilities are more prominent. The result of coupling between resonant combustor acoustics and flame heat release oscillations (Figure 1), combustion instabilities are responsible for component fatigue, reduced engine operability, and increased toxic emissions.

For annular combustor geometries, heat release oscillations can couple with the azimuthal acoustic mode represented in Figure 2a. For an azimuthal standing wave mode, transverse oscillations are produced in the vicinity of the nozzle in accordance with the nozzle location relative to the acoustic nodes.

Experimental Facility

The transverse forcing facility is shown in Figure 3. The facility is equipped with 3 speakers on each side to establish strong transverse acoustic waves that disturb the flow field and subsequently the flame. Large windows grant access for laser and imaging diagnostics.

Velocity Coupled Flame Response

Transverse Acoustic Excitation

Flame Leading Point Motion

Figure 6. Possible flame response pathways during transverse forcing for swirl-stabilized flames.

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Flame Leading Point Motion

• Aerodynamic stabilization of the flame, Figure 7, presents an additional source for flame wrinkles as the flame is not anchored.
• The natural motion of the flame leading point is dominated by the motion of the stagnation point in the recirculation zone.
• The forced motion of the flame leading point, $\xi_{\text{v}}$, is comparable to particle motion induced from acoustic excitation, $\xi_{\text{v}} = |u_{\text{v}}|/\pi f$ known to induce flame wrinkles.

Multi-Nozzle Effects

Vortex-vortex interaction and flame-flame interaction may contribute significant differences to heat release oscillations between single and multi-nozzle facilities. Insight into these effects are paramount for application to gas turbine engines.

Impact: Investigation of the interactions between neighboring flames and flow structures and the flame response to transverse excitation increases the fidelity of flame response modeling allowing advancements in combustor design capabilities to avoid combustion instabilities.

2. C. Sansisul et al., International Journal of Aeroacoustics, 2009