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Fluid Image Velocimetry of the Flow in the Recirculation Zone of a Bluff Body Stabilized and Controlled Burner

B. Golovanevsky, Y. Levy *Faculty of Aerospace Engineering Technion - Israel Institute of Technology - Haifa 32000, Israel

ABSTRACT

Combustion instabilities have been encountered in almost all of the propulsion system development programs. In typical liquid fueled combustors, the most dangerous oscillations are at the frequency of 80-500 Hz. This low-frequency "rumble" is generally characterized by longitudinal acoustic oscillations and should be suppressed for proper operation.

The study is aimed at the investigation of two streams interaction, to understand the physical mechanisms involved in spray combustion instability and its suppression. Here two streams represent the main oscillating flow in an unstable combustor and the oscillating control hot stream.

The study is focused on the experimental investigation of interchamber interaction between the host combustion acoustics and the oscillating spray with its associated heat release near the flame holder.

The laboratory model incorporates the primary oscillating reactive stream, produced by conventional pressure atomizer and pulsating ambient air. A secondary (smaller) pressure sensitive (effervescent) atomizer produces the secondary (control) stream.

Special emphasis was given to diagnostic techniques to analyze the details of the oscillating streams and their interaction. Advanced, with highly improved resolution FIV (Fluid Image Velocimetry) method was applied for velocity field analysis coupled with local measurements of time dependent Pressure, Temperature, CH*- Emission and Velocity. The FIV method is a full-field, two dimensional, nonintrusive, quantitative flow visualization technique which allows high resolution instantaneous measurement of two-dimensional velocity flow field with high accuracy. In addition, the PDA system was used to measure the dynamic spray characteristic (droplet diameter and velocity) and as a calibration method for the FIV system.

It was shown that the use of FIV for velocity mapping simplifies the effort and gives much more detailed result. The extremely high density of calculated velocity field also simplifies and increases accuracy of further calculations based on velocity map (such as vorticity distribution).

The application of various optical diagnostics methods, including the recently modified FIV method, allows the detailed investigation of the special effervescent atomizer and flameholder assembly. The ability of an atomizer to produce oscillating spray and heat release at a wide frequency range as well as its high sensitivity to small pressure perturbation was demonstrated. At some frequencies, 100%-modulated heat was achieved. This allows the use of the special effervescent type atomizer to suppress combustion instability almost completely. Hence, it can be mounted in the flameholder section of typical ramjet combustor and assist in the suppression of its instabilities.

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* - Corresponding author:
Prof. Yeshayahou Levy
Faculty of Aerospace Engineering,
Technion – Israel Institute of Technology,
Haifa 32000, Israel
Tel: 972-4-8293807,
Fax: 972-4-8231848,
e-mail: levyy@aerodyne.technion.ac.il