Characterization of Indirect Combustion Noise Generated in a Single-Element Hydrogen-Oxygen Rocket Combustor

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In this study, the mechanisms of generation and modulation of indirect combustion noise (ICN) produced in a single-element H_2-O_2 rocket combustor configuration are investigated using a hybrid Computational Fluid Dynamics/Computational Aero-Acoustics (CFD/CAA) simulation framework [1,2]. Specifically, 2-D numerical simulation of a confined H_2-O_2 diffusion flame at supercritical pressure is performed using the same single-element coaxial rocket combustor configuration that was experimentally investigated at Pennsylvania State University's Cryogenic Combustion Laboratory [3,4]. The acoustic source mechanisms contributing to ICN production are obtained from the solutions of 2-D Direct Numerical Simulations (DNS) of the supercritical combustion field inside the combustor, and the flow through the exhaust-nozzle at the combustor exit. Several CAA simulations, each considering different acoustic source mechanisms, are carried out by solving the Acoustic Perturbation Equations (APE) [5]. Characterization of the various ICN source mechanisms, such as those due to entropy, compositional, and vorticity inhomogeneities, is conducted, and their individual and collective contributions to the overall ICN are elucidated.

Analysis of the CAA simulations' data shows that for the acoustic field outside the combustor, the Sound Pressure Levels (SPLs) obtained by considering both jet noise and ICN are significantly higher than those obtained by considering only ICN. This indicates that the noise perceived outside the combustor is dominated by jet noise. Additionally, for the ICN propagating outside the combustor, the vorticity source term contributes the most to ICN. In contrast, for the acoustic field inside the combustor, the SPLs computed by considering both jet noise and ICN exhibit virtually the same values for the corresponding frequencies as those computed by considering only ICN. This is a consequence of the nozzle being choked, due to which the jet noise is unable to propagate back into the combustor. Besides, for the ICN propagating back into the combustor, the pressure fluctuations induced by the source terms of entropy and composition are the most dominant. However, since these two pressure fluctuations propagate with a 180° phase shift, their amplitudes cancel each other out. As a result, when all source terms are considered, the resultant SPL becomes smaller compared with the cases in which the entropy source term and the composition source term are considered individually.

References

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