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# High-Fidelity Simulations of an Ultra-Compact Trapped Vortex Combustor with Liquid Fuel Spray

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Ultra-compact trapped vortex combustors are promising for aviation applications. The trapped vortex combustor concept utilizes cavities that lead to recirculation zones, such that a flame can stabilize without being directly exposed to the main flow. This allows for an efficient combustion process with superior fuel-air mixing and increased stability, which makes the trapped vortex combustor particularly promising for compact engines in aviation. In this work, we present high-fidelity simulations of an ultra-compact trapped vortex combustor that has been developed and studied experimentally at the University of Illinois, Urbana-Champaign [1]. The combustor operates on F-24 fuel which is injected as a liquid into two cavities, and forward and backward inlets supply air for establishing efficient mixing and strong cavity vortices. Experiments have been conducted at different operating conditions, and an elevated pressure (3 bar) and an overall equivalence ratio of 0.15 have been chosen for the simulations presented in this work. Fuel spray is treated with a Lagrangian approach, while F-24 combustion chemistry is described by a reduced mechanism with 48 species. The various air inlets are included in the simulation, as well as part of the outlet section downstream of the cavities. The simulations are performed with the low-Mach adaptive mesh refinement reacting flow code PeleLMeX. We present non-reacting validation simulations that compare numerical flow fields with non-reacting PIV data. Reacting flow data is presented with a focus on combustion characteristics and flame stabilization. The simulation results show significant interaction of fresh fuel with recirculated gases as well as extinguishing/igniting flamelets in regions of mixing with fresh air, which feature high shear and scalar dissipation rates. Statistics of key species (e.g., formaldehyde), temperature and heat release rate are presented with respect to flow field and mixing characteristics. In addition, an analysis based on extracted flamelets is presented that provides further insight into features of the flame stabilization and combustion process with respect to mixing and flow field characteristics.

**References**

[1] Shim, H., Wood, E.J., O'Brien, C., Lee, T., Kastengren, A., Mayhew, E., Kim, J., Temme, J. and Kweon, C.B.M., 2024. Combustion Characteristics in an Ultra-Compact Trapped Vortex Combustor with Liquid Fuel Sprays. In AIAA SCITECH 2024 Forum (p. 0579).