

Master's Thesis Defense Announcement
Mechanical and Aerospace Engineering Department
University of Texas at Arlington

COMPUTATIONAL STUDY OF ROTATING DETONATION COMBUSTORS

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Abstract

Rotating detonation combustors (RDCs) are pressure-gain combustion devices that sustain one or more continuously rotating detonation waves, offering potential thermodynamic and performance advantages over conventional deflagration-based systems. Their behavior depends strongly on combustor geometry and operating conditions. Understanding these effects is therefore essential for the design and optimization of practical RDCs. Accordingly, this thesis numerically investigates annular RDCs with two primary objectives: (1) to evaluate the effects of propellant mass flux and (2) to assess the influence of annular width on detonation-wave dynamics and combustor performance.

A finite-volume framework is used to solve the compressible reactive Euler equations with hydrogen-air chemical kinetics. The method employs the AUSM+ scheme for spatial discretization and CFL-based adaptive time stepping for temporal integration. A comparison of a global one-step reaction mechanism with a detailed multistep mechanism shows that the latter more accurately predicts detonation characteristics at an acceptable computational cost. Grid-convergence studies establish the spatial resolution needed to resolve detonation-wave structure and propagation dynamics.

The influence of propellant mass flux is investigated using a two-dimensional (2D) unwrapped RDC model, which retains essential detonation physics while reducing computational cost. The baseline configuration predicts a stable single rotating detonation wave with a dominant frequency of 5.52 kHz and a propagation velocity of 1,656 m/s. This velocity is approximately 85% of the Chapman-Jouguet (CJ) velocity and agrees well with experimental measurements. The simulations show that propellant mass flux strongly affects detonation-wave structure, propagation, and injector-wave interactions. As mass flux increases, the detonation-wave height decreases, indicating stronger confinement of injected reactants and a reduced reactant penetration depth. Furthermore, wave frequency and propagation velocity vary nonlinearly with mass flux due to the competing effects of reactant momentum and post-detonation pressure.

The analysis is extended to three-dimensional (3D) annular RDC configurations to examine geometric confinement. Compared with the 2D model, the 3D baseline simulation predicts lower detonation-wave velocities owing to wavefront curvature, radial pressure gradients, and additional 3D flow interactions. Variations in annular width significantly influence wave structure, propagation velocity, wave height, thrust, and radial pressure distribution within the combustor. Increasing annular width promotes reactant replenishment and combustion-product expansion, leading to higher wave velocities and frequencies and lower wave height as confinement weakens. Although annular width has a pronounced effect on detonation dynamics and thrust production, its effect on specific impulse remains comparatively small.

Overall, propellant mass flux and geometric confinement jointly govern RDC performance through their coupled effects on reactant replenishment, wave propagation, and detonation stability. These findings provide guidance for designing efficient pressure-gain combustion systems.