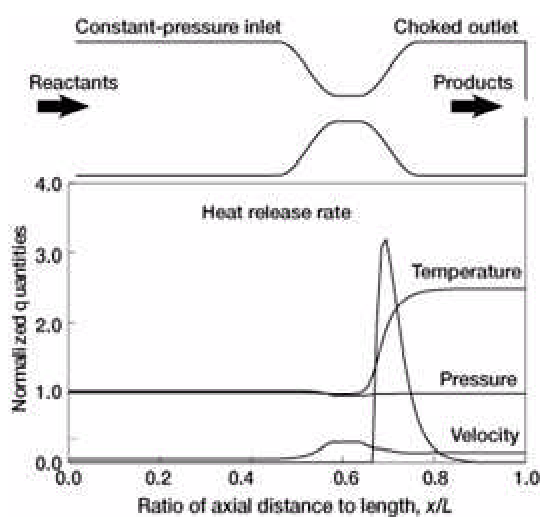
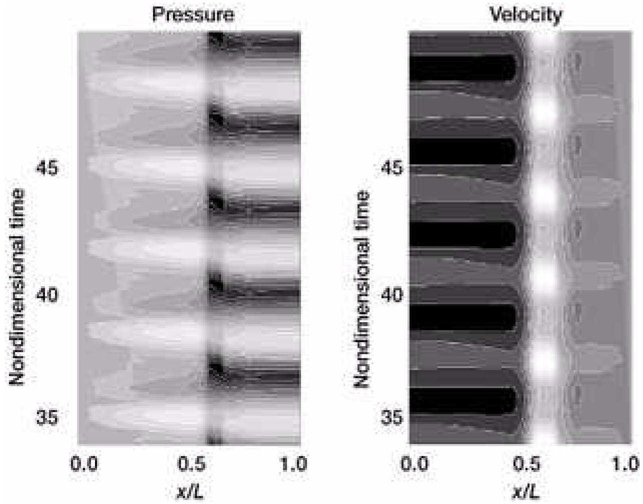
Combustion Instabilities Modeled

NASA Lewis Research Center's Advanced Controls and Dynamics Technology Branch is investigating active control strategies to mitigate or eliminate the combustion instabilities prevalent in lean-burning, low-emission combustors. These instabilities result from coupling between the heat-release mechanisms of the burning process and the acoustic flow field of the combustor.

Control design and implementation require a simulation capability that is both fast and accurate. It must capture the essential physics of the system, yet be as simple as possible. A quasi-one-dimensional, computational fluid dynamics (CFD) based simulation has been developed which may meet these requirements. The Euler equations of mass, momentum, and energy have been used, along with a single reactive species transport equation to simulate coupled thermoacoustic oscillations. A very simple numerical integration scheme was chosen to reduce computing time. Robust boundary condition procedures were incorporated to simulate various flow conditions (e.g., valves, open ends, and choked inflow) as well as to accommodate flow reversals that may arise during large flow-field oscillations.

The accompanying figure shows a sample simulation result. A combustor with an open inlet, a choked outlet, and a large constriction approximately two thirds of the way down the length is shown. The middle plot shows normalized, time-averaged distributions of the relevant flow quantities, and the bottom plot illustrates the acoustic mode shape of the resulting thermoacoustic oscillation. For this simulation, the limit cycle peak-to-peak pressure fluctuations were 13 percent of the mean.





Results from a sample simulation. Top: Combustor diagram. Middle: Time-averaged pressure, temperature, velocity, and heat-release rate. Bottom: Contours of pressure and velocity showing self-sustained, coupled, thermoacoustic oscillations.

The simulation used 100 numerical cells. The total normalized simulation time was 50 units (approximately 15 oscillations), which took 26 sec on a Sun Ultra2.

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