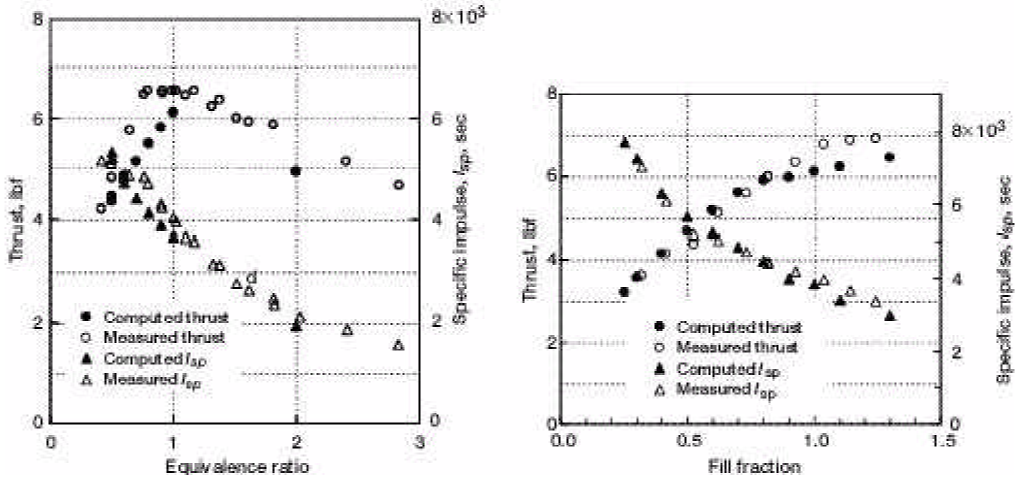
Pulse Detonation Engine Modeled

Pulse Detonation Engine Technology is currently being investigated at Glenn for both air-breathing and rocket propulsion applications. The potential for both mechanical simplicity and high efficiency due to the inherent near-constant-volume combustion process, may make Pulse Detonation Engines (PDE's) well suited for a number of mission profiles.

Assessment of PDE cycles requires a simulation capability that is both fast and accurate. It should capture the essential physics of the system, yet run at speeds that allow parametric analysis. A quasi-one-dimensional, computational-fluid-dynamics-based simulation has been developed that may meet these requirements. The Euler equations of mass, momentum, and energy have been usedalong with a single reactive species transport equation, and submodels to account for dominant loss mechanisms (e.g., viscous losses, heat transfer, and valving) to successfully simulate PDE cycles. A high-resolution numerical integration scheme was chosen to capture the discontinuities associated with detonation, and robust boundary condition procedures were incorporated to accommodate flow reversals that may arise during a given cycle.

The accompanying graphs compare experimentally measured and computed performance over a range of operating conditions for a particular PDE. Experimental data were supplied by Fred Schauer and Jeff Stutrud from the Air Force Research Laboratory at Wright-Patterson AFB and by Royce Bradley from Innovative Scientific Solutions, Inc. The left graph shows thrust and specific impulse, I_{sp}, as functions of equivalence ratio for a PDE cycle in which the tube is completely filled with a detonable hydrogen/air mixture. The right graph shows thrust and specific impulse as functions of the fraction of the tube that is filled with a stoichiometric mixture of hydrogen and air. For both figures, the operating frequency was 16 Hz. The agreement between measured and computed values is quite good, both in terms of trend and magnitude. The error is under 10 percent everywhere except for the thrust value at an equivalence ratio of 0.8 in the left figure, where it is 14 percent.

The simulation results shown were made using 200 numerical cells. Each cycle of the engine, approximately 0.06 sec, required 2.0 min of CPU time on a Sun Ultra2. The simulation is currently being used to analyze existing experiments, design new experiments, and predict performance in propulsion concepts where the PDE is a component (e.g., hybrid engines and combined cycles).



Measured and computed thrust and specific thrust. Left: As functions of equivalence ratio for 100-percent fill, 50-percent purge, 16-Hz PDE cycle. Right: As functions of fill fraction in a 50-percent purge, 16-Hz stoichiometric PDE cycle.

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