INDUCTION TIME EFFECTS IN PULSE COMBUSTORS*

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1 Introduction

Combustion systems that take advantage of a periodic combustion process have many advantages over conventional systems. Their rate of heat transfer is greatly enhanced and their pollutant emissions are lower. They draw in their own supply of fuel and air and they are self-venting. They have few moving parts.

The most common type of pulse combustor is based on a Helmholtz resonator – a burning cycle drives a resonant pressure wave, which in turn enhances the rate of combustion, resulting in a self-sustaining, large-scale oscillation. Although the basic physical mechanisms controlling such a process were explained by Rayleigh over a century ago, a full understanding of the operation of a pulse combustor still does not exist. The dominant processes in such a system – combustion, turbulent fluid dynamics, acoustics – are highly coupled and interact nonlinearly, which has reduced the design process to a costly and inefficient trial-and-error procedure.

Several recent numerical and experimental studies, however, have been focused towards a better understanding of the basic underlying physics. Barr et al. [1] have elucidated the relative roles of the time scales governing the energy release, the turbulent mixing, and the acoustics. Keller et al. [3] have demonstrated the importance of the phase relation between the resonant pressure field in the tailpipe and the periodic energy release. Marcus et al. [4] have developed the capability for a fully three-dimensional simulation of the reacting flow in a pulse combustor. This paper is an application of that methodology to a detailed investigation of the frequency response of the model to changes in the chemical kinetics.

The methodology consists of a fully conservative seond-order Godunov algorithm for the inviscid, reacting gas dynamics equations coupled to an adaptive mesh refinement procedure[2]. We carry out quasi-one-dimensional and axisymmetric simulations. For the axisymmetric simulations, we couple a second-order, unsplit Godunov algorithm for the inviscid, reacting gas dynamics equations to an adaptive Cartesian grid scheme[5].

In order to keep computational costs relatively low, we have developed a "bootstrap" procedure to initialize progressively higher-dimensional calculations. The quasi-one-dimensional code is run until transient phenomena have subsided and a desirable quasi-steady state has been achieved. The state data is then extrapolated to axisymmetric coordinates and these conditions used to initialize an axisymmetric calculation.

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