Cesium-based Velocimeter for Model Validation

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Overview

A diode-laser velocimeter based on cesium absorption spectroscopy has been used to measure the axial burned gas velocity in a pulse detonation engine (PDE) configured with and without a converging-diverging nozzle. These data are compared to simulation data from a frozen-chemistry computational model, as well as a finite-rate chemistry model with and without the effects of heat transfer included. Discrepancies between the data and the models are discussed and conclusions are drawn on the validity of each model.

The velocity diagnostic requires cesium to be seeded into the PDE flowfield where it is then detected using a fixed-wavelength diode laser tuned to monitor the D2 transition of atomic cesium near 852 nm. Due to the unsteady nature of the PDE flowfield, the deposition of the cesium absorber into the flowfield occurs in a pulsating manner. The unsteady nature of this seeding process enables a time-of-flight measurement to be made as the absorber passes two parallel laser beams spaced 2 to 3 mm apart in the streamwise direction. Using this technique, PDE gas velocities ranging from -100 to 1000 m/s are measured with 20 to 100 µs time resolution over the duration of a single cycle. Results are presented for a C2H4/O2 (phi = 1) fueled PDE operating both with and without a converging-diverging nozzle.

Comparison of velocity data to each computational model suggests that for the case of the straight tube PDE, velocity can be accurately predicted over the thrust producing range of the engine cycle via an idealized, frozen-chemistry computational model. For the PDE outfitted with a converging-diverging nozzle, the blowdown time for a single cycle is substantially longer, and a less-idealized, finite-rate chemistry model which accounts for heat loss effects is required to capture the more complex wave dynamics.

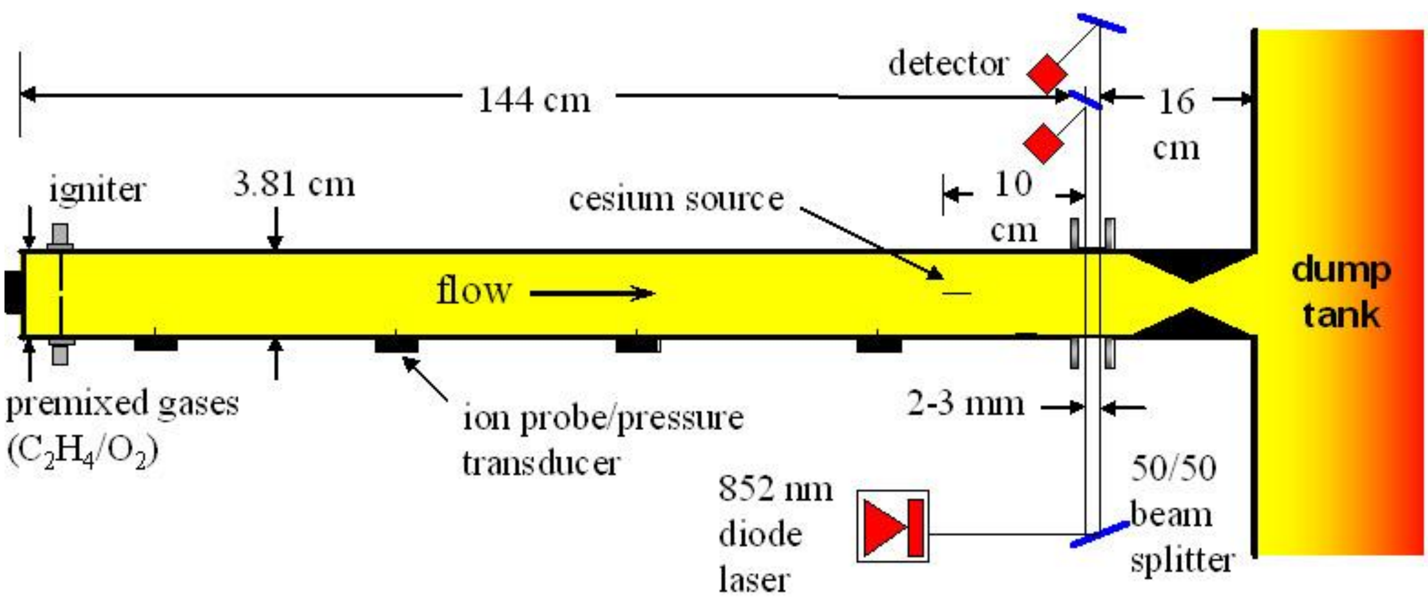

Figure 1: Schematic of Stanford PDE facility with cesium-based velocimetry diagnostic

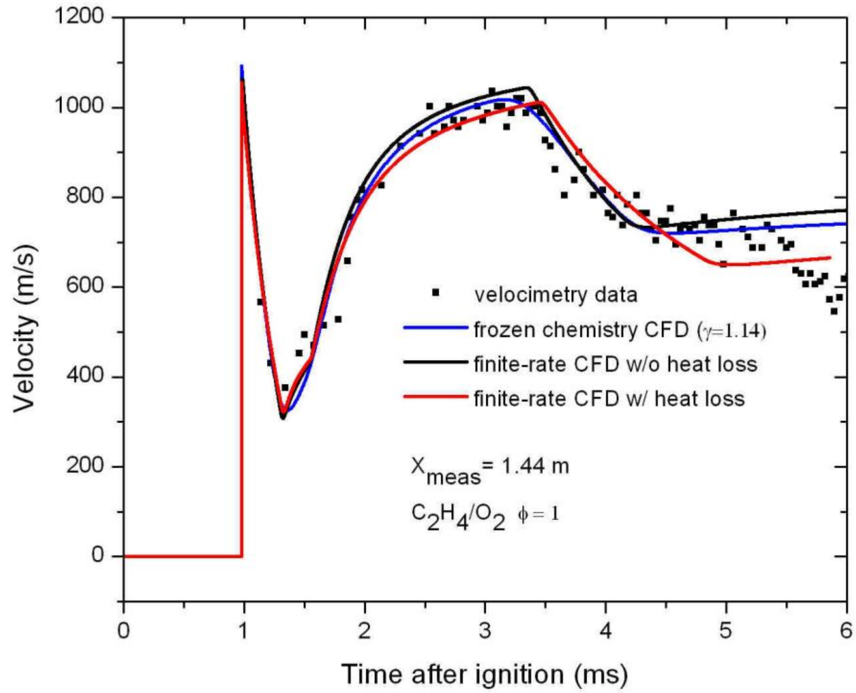

Figure 2: Velocimetry data for straight-tube PDE plotted against model data

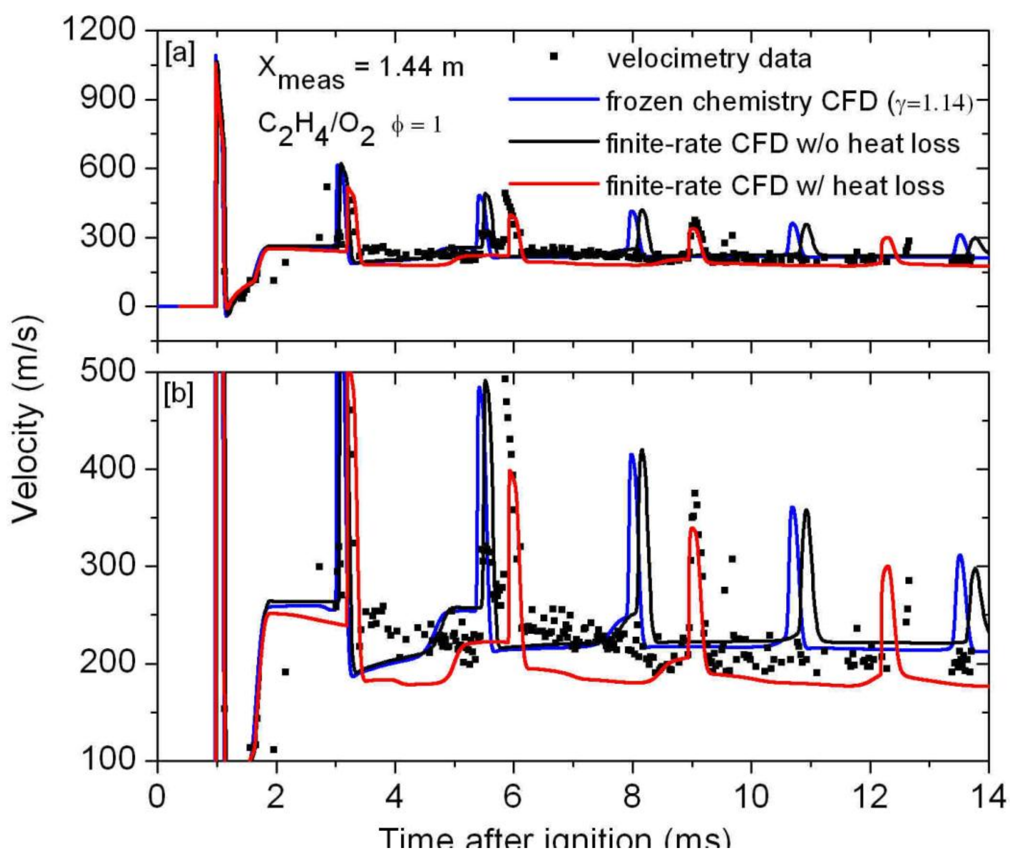

Figure 3: Velocimetry data for converging-diverging nozzle configured PDE plotted against model data. Window [b] shows a region of window [a] with the vertical axis rescaled