Study on reflected shock bifurcation dynamics

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Shock tube experiments on ignition delay time and species evolution in fuel-oxidizer-diluent mixtures are now a standard approach in combustion studies. In an effort to avoid nonideal effects, most studies use highly diluted mixtures and careful attention to operating parameters. However, in order to study fuels under real conditions, it is needed to work with a dilution level on the order of 75-80% (to mimic fuel-air mixtures). For these cases, the interaction of the reflected shock wave with the boundary layer behind the incident shock can create substantial flow nonuniformity that will significantly affect the data. This is manifested by the creation of an oblique shock precursor running into the boundary layer region ahead of the main reflected shock wave, usually termed ”shock bifurcation”.
Empirical models and experimental data on shock bifurcation in selected mixtures are available but there are few systematic studies of the onset and growth of the bifurcation region and most of them are limited to one location and pressure measurements in highly diluted mixtures. Thus, the goal of this study is to analyze the dynamics of shock bifurcation via imaging, pressure, and laser-based measurements.
Series of experiments have been conducted in the GALCIT Detonation Tube at Caltech operated as a shock tube. The facility is a 7.6 m long, 28 cm in inner diameter tube with a rectangular cookie-cutter 15.2 cm wide. Visualization section consisted of a splitter plate, situated in the middle of the channel, with a reflecting wall positioned at the end of the observation region and two quartz windows. EverGreen70 Q-switched laser was used as a pulsed source of light. Images were taken with a PCO.2000 14-bit camera.
Schlieren and shadowgraph images together with pressure traces were recorded in order to analyze the bifurcation zone geometry in air, carbon dioxide and nitrous oxide. Experiments were conducted for three distances from the endwall – 13, 25 and 53 mm for Mach numbers ranging from 1.5-3 and for distances ranging between 10-90 mm for M = 2.6. The bifurcation foot length was found to linearly increase with increasing Mach number and distance from the endwall, the foot angle was found to decrease with increasing Mach number. The present data tend to show that generally accepted assumptions of the stagnation pressure behind the oblique shock are not valid. Experimental results were compared to the numerical simulations of Ziegler and satisfactory agreement was observed for N_2O in terms of bifurcation foot height as a function of distance to the end wall, however, the comparison of results for air showed disagreement.

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