Cellular Flame Interaction with a Strong Vortex

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The problem of a flame interacting with a strong vortex is of interest for many applications such as turbulent combustion and flame acceleration studies. Following the ignition of a flame in a geometry with obstructions, the flame-driven flow generates start-up vortices downstream of obstructions present in the flow field. The present experimental/numerical research program seeks to establish a repeatable method to study the interaction of a flame with a start-up vortex in a canonical experiment.

Experiments are performed in a thin rectangular shock tube open at one end in which the flame is ignited near a solid wall. A rectangular obstacle is placed near the center of the tube. Following the ignition of the flame in different stoichiometric blends of hydrogen and methane, flow is driven towards the open end of the tube as a result of the volumetric expansion of gas. The impulsive motion of the flow over the backwards-facing step generates a start-up vortex which grows over time. The flame eventually propagates over the obstacle and is entrained by the vortex. The flame time and Markstein length are conjectured to be the important parameters governing the resulting enhancement of the flame.

This problem is modeled numerically using two-dimensional reactive Navier-Stokes equations. The flame is advanced using a level-set method, in which the flame propagates normal to itself at a fixed burning velocity. The chemical timescale is varied for a fixed burning velocity to study the effect of the chemical timescale on the enhancement of the flame. A second series of tests are performed in which the flame is modelled using a one-step Arrhenius reaction such that the flame Markstein number can be varied while fixing the chemical timescale.