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Detonation Cell Size in Realistic Fuels: Experiments vs. Numerical Simulations

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Instabilities inherent in multi-dimensional detonations manifest themselves as cellular structures, whose characteristic length scale, i.e., detonation cell size, is empirically connected to various critical dynamical parameters, including minimum channel size, critical tube diameter, and detonation initiation energy, to name a few [1, 2]. Therefore, ability to predict accurately the cell size is key for the design and proper operation of detonation-based propulsion devices. Prior research has shown that high-fidelity numerical simulations with multi-step chemical kinetics are unable to predict the experimental cell sizes for hydrogen–air mixtures even at atmospheric conditions. In this work, we extend these results to a wide range of fuels, from hydrogen and low-molecular-weight hydrocarbons, such as methane, to heavy hydrocarbons, such as JP-10. We systematically investigate the morphologies of detonation cells over a range of initial pressures and temperatures, effective activation energies, and specific heat ratios known to control cell regularity. Numerical soot foils for each case are then contrasted with their respective experimental measurements. The comparison shows a persistent discord between simulations and experiments, and also reveals a number of limitations in the present physicochemical models. A differential diagnosis is then performed to assess such limitations in various thermochemical sub-models used in detonation modeling.

References

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