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Combustion Regimes in Supersonic Reactive Under-Expanded Jets

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There exists a number of methods to form a detonation wave in an experimental or practical system. The most commonly studied, and used, approach involves freely propagating planar or quasi-planar detonations, which are found in pulsed or rotating detonation engines. A less studied class of methods of organizing detonative combustion is the standing detonation, which is quasi-stationary in the laboratory frame. Ramp-stabilized oblique detonation waves have been demonstrated in the past [1]. At the same time, attempts to stabilize standing normal detonations have generally been unsuccessful [2, 3], though there is some evidence a standing normal detonation could exist as an evolution of the oblique detonation mode for certain inflow conditions and ramp angles [4, 5]. Here, highly under-expanded, premixed, supersonic reacting jets are numerically investigated using simplified single-step Arrhenius kinetics with jet conditions and chemical properties systematically varied to study a wide range of resulting supersonic combustion regimes, including a standing normal detonation wave behind a jet Mach stem. A theoretical framework is developed for the prediction of combustion modes and flow conditions required for the detonation formation. This framework provides insights into why previous experimental attempts to form a standing, normal, aerodynamically stabilized detonation had failed. In addition to a standing normal detonation, a wide variety of quasi-stable and unstable combustion regimes in supersonic jets are observed and described in detail. Finally, we highlight the potential benefits of such a configuration for studies of premixed supersonic combustion in general, and detonation waves in particular.

References

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