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Entropy generation in intrinsically unstable premixed flames

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Direct numerical simulations with multi-step chemistry were performed for two-dimensional freely-propagating laminar premixed flames of methane-air and hydrogen-air mixtures with a matching density ratio to isolate the effects of hydrodynamic instability while allowing for a variable effective Lewis number, with methane (hydrogen) flame being thermodiffusively stable (unstable). Entropy generation mechanisms were analyzed based on contributions from heat conduction, viscous dissipation, mass diffusion, and chemical reactions [1]. Across both flames, chemical reactions were identified as the dominant source of entropy generation, with viscous dissipation contributing negligibly compared to other mechanisms. In the hydrogen flame, the presence of thermodiffusive instabilities was associated with a higher rate of entropy generation, concentrated in a smaller region compared to the methane flame, a trend evident in both the absolute values and the data dispersion. Temporal analysis revealed that the total entropy generation rate could mark the transition from an initial linear to a non-linear regime of flame development. Entropy-based stability criteria based on non-equilibrium thermodynamics [2] confirmed the presence of instabilities and showed a potential to capture the difference in instability levels between the two cases.

References

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