



Numerical studies of confinement effects on premixed-gas flame propagation

D. Fernández-Galisteo^{1*}, A. Dejoan¹, R. Palomeque-Santiago², M. Rubio-Rubio², J. Melguizo-Gavilanes³, M. Sánchez-Sanz², P.D. Ronney⁴, V.N. Kurdyumov¹

*Lead presenter: d.galisteo@ciemat.es

¹ Energy Department, Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Avda. Complutense 40, 28040, Madrid, Spain

² Departamento de Ingeniería Térmica y de Fluidos, Universidad Carlos III de Madrid, 28911 Leganes, Madrid, Spain

³ Shell Global Solutions B.V., Major Hazards Management, Energy Transition Campus, 1031 HW Amsterdam, The Netherlands

⁴ Department of Aerospace and Mechanical Engineering, University of Southern California, Los Angeles, CA, USA

The propagation of isobaric premixed flames into a quiescent fuel-oxidizer gas mixture confined between two closely-spaced parallel plates is investigated numerically. We approach the problem by employing the narrow-channel approximation [1], which reduces the governing equations from 3D to a quasi-3D form. With this approximation, the momentum equation is simplified to Darcy's law. First, we examine the impact of confinement using a single-step Arrhenius reaction model with unity Lewis number, where only hydrodynamic instabilities are present. Comparisons with 2D simulations (unconfined geometry), reveal that loss of momentum enhances the hydrodynamic instability [2]. Next, we include the diffusive-thermal mechanism by incorporating a reduced hydrogen kinetics for fuel-lean conditions (e.g., effective Lewis number around 0.3) [3, 4]. In this case, momentum loss further elongates the finger-like structures characteristic of diffusive-thermal unstable fronts, increasing the overall propagation rate. Additionally, we analyze the effect of heat losses, which are responsible for the transition to one-headed and two-headed isolated flame cell propagation [5]. Finally, we present full 3D simulations of ultra-lean hydrogen flames to support our analysis of confinement effects.

References

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