International Conference on Numerical Combustion
Rome, Italy, October 14-17, 2025
www.icnc2025.com

Thermodiffusive effects in laboratory-scale Bunsen flames with lean premixed hydrogen/methane blends

A. Moitro*, E. F. Hunt, A. J. Aspden
*Lead presenter: arnab.moitro@newcastle.ac.uk
School of Engineering, Newcastle University, Newcastle-Upon-Tyne, United Kingdom

Lean premixed flames of hydrogen-methane blends can be strongly affected by thermodiffusive effects arising from the low Lewis number of the fuel, resulting in large variations in local flame speed, thickness and fuel consumption rate. For such flames, measurements of turbulent flame speed and flame stretch factor are challenging, as these quantities become sensitive to the choice of progress variable and the isosurface on which they are measured. Such uncertainty is a challenge for large eddy simulation (LES) closure models (e.g. based on flame speed and flame surface area wrinkling factor), and need to account for an array of sub-filter thermodiffusive effects, such as local flame curvature, generation of wrinkled cellular structures, sub-filter turbulence-flame interactions, etc. In the present work, direct numerical simulations (DNS) of laboratory-scale Bunsen flames have been conducted to reproduce the Cambridge premixed turbulent piloted Bunsen flame [1]. Lean premixed hydrogen-methane blends have been considered over a broad range of conditions for blend fraction and equivalence ratio, spanning a large range of thermodiffusive instability parameter, ω_2. Consistent with [2], there are essentially two flames, aligned with curvature: hydrogen preferentially diffuses into regions of positive curvature (centre of curvature in the products), which results in a richer, faster, thinner flame; the methane if left behind in the negatively-curved regions, which burns relatively slower and thicker. Using the local flame speed model proposed in [2] based on [3], combined with the flame surface wrinkling model from [4], a model is proposed to predict the jet flame height, and demonstrated to be consistent with the simulations. Finally, the influence of thermodiffusive effects on several classical LES turbulent-flame models are examined a priori by explicit filtering of the DNS data for direct evaluation of the closure terms.

References

[1] O. Chaib, Y. Zheng, S. Hochgreb, I. Boxx. Hybrid algorithm for the detection of turbulent flame fronts. *Experiments in Fluids.* 2023;64(5):104.

[2] E. F. Hunt, A. Moitro, T. L. Howarth, A. J. Aspden. A DNS comparison of thermodiffusively-unstable lean premixed hydrogen-methane blends in a lab-scale combustor and canonical flames-in-a-box. *Proceedings of the European Combustion Meeting.* 2025.

[3] T. L. Howarth, E. F. Hunt, A. J. Aspden. Thermodiffusively-unstable lean premixed hydrogen flames: Phenomenology, empirical modelling, and thermal leading points. *Combustion and Flame.* 2023;253:112811.

[4] E. F. Hunt, A. J. Aspden. Thermodiffusively-unstable lean premixed hydrogen flames: Length scale effects and turbulent burning regimes. *Combustion and Flame.* 2025;272:113855.