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

Flame-wall interaction in a lean H_2/CH_4 low-swirl flame

Chabot O.[1]*, Nozari M.[1], Jella S.[2], Vabre M.[1], Fan L.[3], Vena P.[3], Day M.[4], Esclapez L.[4], Savard B.[1]
*Lead presenter: olivier.chabot@polymtl.ca
[1] Polytechnique Montréal, Canada
[2] Siemens Energy Canada Limited, Canada
[3] National Research Council, Canada
[4] National Renewable Energy Laboratory, United States

We present a direct numerical simulation (DNS) of a lean, low-swirl, premixed H_2/CH_4 flame impinging on an inclined isothermal wall. The configuration corresponds to a laboratory-scale open flame with a Reynolds number of 20,000 and a nominal Karlovitz number of 300, as detailed in [1]. The fuel-air mixture consists of 70% hydrogen and 30% methane, by volume, at equivalence ratio $\phi = 0.41$. Simulation results are compared with experimental data from OH and CH_2O PLIF, and stereo-PIV measurements. The mean and rms velocity, and the contours of OH mass fraction from the simulation, agree qualitatively with experimental data. A large cloud of CH_2O attributed to incomplete combustion is consistently observed in both the numerical and experimental flames.
Air entrainment causes the flame to interact with the wall at a lower equivalence ratio than that of the inlet, with peak wall heat loss occurring around $\phi = 0.25$. Yet, the mean wall heat loss is on the order of 10% of the nominal flame power (*i.e.*, at $\phi = 0.41$). The wall heat loss normalized by flame power based on local equivalence ratio reaches mean values three orders of magnitude larger in the leaner mixtures. These large values are attributed to increasingly strong heat release rate (HRR) enhancement towards the leanest mixtures, compared with HRR in a corresponding unstretched laminar flame at the same equivalence ratio. The role of back support and mean strain rate on HRR enhancement is presented.
The quenching Peclet number Pe_{Q}, computed as the minimum value of Pe on a temperature isosurface, shows little variation with respect to the local equivalence ratio on the isosurface. Small values of Pe_{Q} observed locally in lean regions can be attributed to local HRR enhancement. When computed with the flame thickness based on local equivalence ratio, $Pe(\phi)$ decreases with decreasing ϕ and reaches values multiple orders of magnitude smaller than unity.
The large amount of CH_2O from incomplete combustion is not associated with enthalpy loss at the wall, but rather due to the flame being sustained at very lean equivalence ratios, which leads to large chemical timescales, thus preventing CH_2O consumption within the simulation domain.

References

[1] L. Fan, B. Savard, S. Carlyle, M. Nozari, R. Naaman, B. Fond, P. Vena, Simultaneous stereo-PIV and OH×CH2O PLIF measurements in turbulent ultra lean CH4/H2 swirling wall-impinging flames, Proceedings of the Combustion Institute (2022).