

Impact of Thermal and Preferential Diffusion on the Dynamics and Acoustics of Premixed Hydrogen-Air Flames

Z. Shahin^{1*}, B. Pedro¹, A. Schillaci¹, M. Meinke¹, D. Krug¹, W. Schröder^{1,2}

*Lead presenter: z.shahin@aia.rwth-aachen.de

¹ Institute of Aerodynamics, RWTH Aachen University, Wüllnerstr. 5a, 52062 Aachen, Germany

² JARA Center for Simulation and Data Science, RWTH Aachen University, Seffenter Weg 23, 52074 Aachen, Germany

The influence of thermal and preferential diffusion on hydrogen flames has been demonstrated [1, 2], but their effects on flame dynamics and acoustic emission remain less explored. Here, laminar hydrogen–air slit flames are investigated using two-dimensional direct numerical simulations (DNS) combined with modal decomposition. Simulations cover equivalence ratios from ($\phi = 0.4$ – 0.7) and diffusion models, including mixture-averaged diffusion with and without the Soret effect and a simplified unity Lewis number approximation. POD and DMD reveal that dominant hydrodynamic instabilities persist across models, particularly at richer conditions. However, the inclusion of Soret and preferential diffusion modifies the spectral structure of the dominant modes, such that energy is redistributed across higher-order components and a shift in the acoustic peak frequency is induced. At lean conditions, diffusion drives the dominant instability, while at richer conditions it modulates the spectral features of hydrodynamic modes. Neglecting thermal and preferential diffusion fails to capture this behavior, potentially leading to underestimated sound levels at key hydrodynamic frequencies. These findings highlight the importance of detailed diffusion modeling to accurately predict combustion generated noise in hydrogen systems.

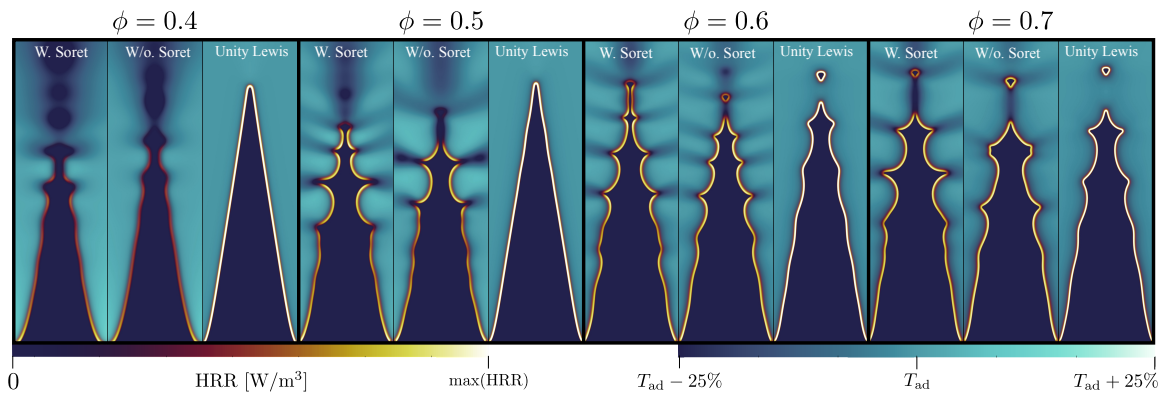


Figure 1: Instantaneous heat release rate (HRR) and temperature contours for four equivalence ratios (blocks from left to right: $\phi = 0.4$ to 0.7). Each block includes different transport model: with Soret diffusion (W. Soret), without Soret diffusion (W/o. Soret), and Unity Lewis number (Unity Lewis).

References

- [1] Wen, X. et al. Thermodynamically unstable laminar hydrogen flame in a sufficiently large 3D computational domain–Part I: Characteristic patterns. *Combustion and Flame*. 2024.
- [2] Liang, Wenkai, et al. Effects of Soret diffusion on the laminar flame speed and Markstein length of syngas/air mixtures. *Proceedings of the Combustion Institute* 2013.