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DNS-driven modeling for filtered lean premixed hydrogen-air flames

C. Matteucci[1]*, S. Bottari[1], D. Cavalieri[1], D. Schintu[1], F. d'Alessio[1], P.E. Lapenna[1], F. Creta[1]
*Lead presenter: chiara.matteucci@uniroma1.it
[1] Department of Mechanical and Aerospace Engineering, Sapienza University of Rome, Italy

Carbon-free fuels such as hydrogen and ammonia can burn very differently from hydrocarbons. When premixed with air or oxygen, the ensuing premixed flame generally exhibits a complex multiscale cellular conformation, due to the effect of intrinsic thermodiffusive instability, which originates when a controlling reactant such as hydrogen has a high diffusivity with respect to thermal diffusivity. This can lead to a drastic increase in the global burning rate (or consumption speed) with respect to hydrocarbons, something of concern for the static stability of operation in gas turbine combustion chambers. Such increased flame corrugation, as well as local changes in reactivity, are challenging to model in an LES laminar context and even more so in a turbulent setting where a complex interaction exists between the scales of turbulence and the characteristic scales of the intrinsic instability.

In order to accurately model the effect of intrinsic instabilities on the morphology and stretching patterns of a premixed flame, we propose a data-driven approach which utilizes a sufficiently small-size DNS training dataset which is adequately representative of a multiscale, unsteady flame subject to such instabilities[1]. The dataset is utilized to construct a low-dimensional manifold (LDM) in the form $\psi(C_1,C_2,...)$ here C_i are the independent set of generalized progress variables and ψ is the thermochemical quantity of interest.

Once the LDM is constructed, the LES model solves transport equations for the set of generalized progress variables. The filtered equations contain a set of unclosed terms which are modeled following a multidimensional F-TACLES approach based on the spatial filtering of the original DNS data[2]. In addition, the synergistic interaction of the intrinsic instabilities can be modeled following recently developed approaches.

References

[1] Remiddi A. et al. Data-driven modeling of resolved and filtered thermo-diffusively unstable hydrogen-air flames. *Proceedings of the Combustion Institute*. 2024;40.1:105713.

[2] Fiorina B. et al. A filtered tabulated chemistry model for LES of premixed combustion. *Combustion and Flame*. 2010;257.3:465-475.