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

Dynamic modelling of sub-grid-scale flame wrinkling for multi-regime combustion

Samuel DILLON[1]*, Denis VEYNANTE[2], Renaud MERCIER[1], Vincent MOUREAU[3], Benoit FIORINA[2]

*Lead presenter: samuel.dillon[at]safrangroup.com

[1] Safran Tech, Digital Sciences and Technologies Department, Safran Tech, France

[2] Université Paris-Saclay, CNRS, CentraleSupélec, Laboratoire EM2C, France

[3] CNRS, INSA Rouen Normandie, CORIA UMR 6614, France

Large-eddy-simulation (LES) of reactive flows is widely used in both academic and industrial applications. Combustion phenomena occur at a scale often smaller than the LES mesh size, therefore, turbulent combustion models are required to account for unresolved turbulent flame interactions. The modeling of sub-grid-scale (SGS) flame turbulence interactions can be described with a flame surface wrinkling factor which measures the ratio of the total flame surface area to the resolved flame surface area [1]. Flame surface wrinkling models are often expressed by assuming equilibrium between turbulent motions and flame surface wrinkling, however, in realistic burners non-equilibrium is present and dynamic models are needed to adapt model parameters [2, 3, 4]. Current dynamic models identify flame surface areas from scalars such as the progress variable $\widetilde{c}$ or the mixture fraction $\widetilde{z}$, however, in multi-regime flames where filtered gradients of $\widetilde{c}$ and $\widetilde{z}$ can coexist, these approaches tend to fail. This work introduces a multi-regime dynamic formalism for determining flame wrinkling factors based on a mixed approach between premixed and diffusion flame surfaces. Model validation is performed using a well-resolved LES database of the HYLON configuration, a dual-swirl coaxial H_2/air injector. The operating condition of interest is the lifted flame, HYLON L, which was studied in the framework of the turbulent flame workshop TNF [5]. This flame has characteristic behavior of both non-premixed and partially-premixed flames, allowing the model to be tested under conditions where iso-surfaces of $\widetilde{c}$ and $\widetilde{z}$ coexist.

References

[1] Fabrice Charlette, Charles Meneveau, and Denis Veynante. “A power-law flame wrinkling model for LES of premixed turbulent combustion Part I: Non-dynamic formulation and initial tests”. In: *Combustion and Flame* 131.1-2 (2002), pp. 159–180.

[2] Massimo Germano et al. “A dynamic subgrid-scale eddy viscosity model”. In: *Physics of Fluids A: Fluid Dynamics* 3.7 (1991), pp. 1760–1765.

[3] Fabrice Charlette, Charles Meneveau, and Denis Veynante. “A power-law flame wrinkling model for LES of premixed turbulent combustion Part II: dynamic formulation”. In: *Combustion and Flame* 131.1-2 (2002), pp. 181–197.

[4] Thomas Schmitt, Matthieu Boileau, and Denis Veynante. “Flame wrinkling factor dynamic modeling for large eddy simulations of turbulent premixed combustion”. In: *Flow, Turbulence and Combustion* 94 (2015), pp. 199–217.

[5] Andrea Aniello et al. “Experimental and numerical investigation of two flame stabilization regimes observed in a dual swirl H2-air coaxial injector”. In: *Combustion and Flame* 249 (2023), p. 112595.