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Flamelet LES of coaxial dual-swirl hydrogen flames with differential diffusion and heat losses

Xiaojuan Ye[1], Xu Wen[1,*], Christian Hasse[2]
*Lead presenter: xu.wen@ustc.edu.cn
[1] State Key Laboratory of Fire Science, University of Science and Technology of China, PR China
[2] Simulation of Reactive Thermo-Fluid Systems, TU Darmstadt, Germany

Large eddy simulation (LES) are conducted for coaxial dual-swirl stabilized turbulent hydrogen flames, i.e., the HYLON burner [1], using the flamelet model with differential diffusion and heat losses to the wall being considered. Depending on the competition between turbulent flow and hydrogen-air chemical timescales, both anchored and lifted flames can be obtained, which are predicted by the flamelet/LES. The effects of differential diffusion are considered by solving the flamelet equations with non-unity constant Lewis numbers, while additional terms are introduced in the governing equations for the manifold coordinates. The effects of heat losses are incorporated in the flamelet model by solving the flamelet equations with modified boundary conditions, while total enthalpy is introduced as one of the trajectory variables with its transport equation being solved. The turbulence-chemistry interactions are considered with presumed probability density functions for the manifold coordinates. The simulation results are compared to the available experimental data, including the mean and RMS velocities of the isothermal flow and the reacting cases, and normalized OH^* for different operating conditions. The stabilization mechanism of both flames is analyzed and the importance of differential diffusion is quantified making use of the proposed flamelet model. Figure 1 shows the overall flame structure under different operating conditions with the first one attached to the lips of the injector (flame A) and the second one lifted-off from the injection system (Flame L).

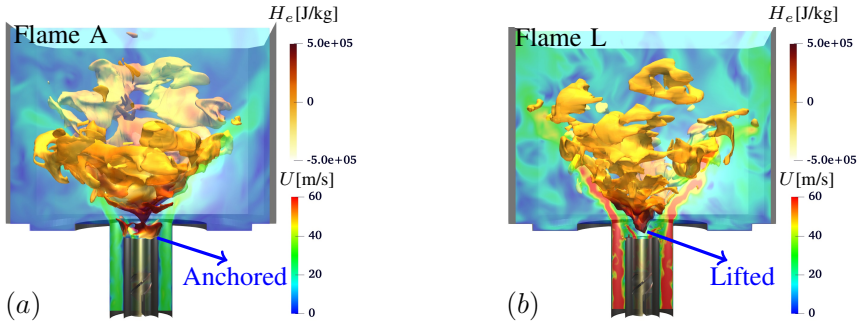

Figure 1: 3D iso-surface showing the instantaneous flame structure corresponding to $T_{st} = 1406$K colored by the local enthalpy value. (a) Anchored flame; (b) Lifted flame. The middle cut-plane showing the instantaneous velocity field is superimposed.

References

[1] Aniello A, Laera D, Marragou S, Magnes H, Selle L, Schuller T, Poinsot T. Experimental and numerical investigation of two flame stabilization regimes observed in a dual swirl H_2-air coaxial injector. *Combustion and Flame*. 2023;249:112595.