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

Dynamics of lean partially-premixed hydrogen flames in a dual-coaxial swirled injector: flame anchoring and helical modes interactions

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Swirled partially-premixed flames, increasingly studied for hydrogen combustion, are known to be stabilized by the appearance of inner and outer recirculation zones [1]. It is also recognized that hydrodynamic instabilities like the Precessing Vortex Core (PVC) can emerge and influence these flame dynamics. Early studies suggest that the PVC may dissipate in the presence of a flame [2], although more recent research, including studies by Stöhr et al. [3] and Boeck et al. [4], evidence that it can persist and in that case it actively influences the dynamics of partially-premixed hydrocarbon flames. The interaction between a PVC and a flame has primarily been studied in the context of lifted flames. Since, partially-premixed hydrogen flames are difficult to lift-off, the potential importance of the precessing or not, and the interaction of the PVC with such flames may appear more critical and needs further understanding.

In this study, the periodic rotation of a hydrogen flame anchoring mechanism is numerically investigated for the HYLON partially-premixed burner within a dual-coaxial swirled configuration. In accordance with experiments, two co-rotating hydrodynamic modes are identified by the simulation near the hydrogen injector lips: an inner PVC at f_1=1910 Hz and an outer shear layer vortex shedding at f_2=1300 Hz. Despite the distinct frequencies of these phenomena, a nonlinear interaction between these modes leads to a strong hydrodynamic interaction mode for which the shear layer at the frontier of these two modes is modulated around the perimiter of the injector, at a frequency close to f_3=f_1-f_2. This modulation is observed to interact with the flame by changing locally the scalar dissipation rate along the circular injector lip, which in turn affects both the anchoring and quenching of the flame tip. This process is the primary mechanism driving the observed rotating flame anchoring phenomenon.

References

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