Thermal Radiation Effects in Large-Eddy Simulation of Methane Oxy-Flames Stabilized on a Swirled Co-Axial Injector

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The transition towards cleaner energy sources has positioned oxy-combustion as a promising pathway for enabling Carbon Capture and Storage (CCS), thereby reducing CO_2 emissions. Oxy-combustion, involving the combustion of natural gas (primarily methane) with pure oxygen or oxygen-enriched air, produces exhaust gases mainly comprising CO_2 and H_2O, thus simplifying downstream separation and capture. The combustion process's inherent complexity arises from the intricate interaction between heat release, fluid flow dynamics, and heat transfer mechanisms, particularly those governed by radiative processes. Therefore, accurate modeling techniques are crucial for capturing and optimizing oxy-combustion flame behavior.

This study focuses on Flame A1 from the Degenève et al. dataset [1,2], characterized by its M-shaped structure stabilized on a swirled co-axial injector. The dataset contains flame shape (OH-PLIF), velocity field and wall temperature measurements. The primary objective is to investigate the combustion characteristics of Flame A1 using Large Eddy Simulation (LES) with the YALES2 [3] code from CORIA, incorporating radiative effects through the Quasi Monte Carlo (QMC) method in the RAINIER [4] code and detailed radiative properties for walls (large optical access in the combustion chamber) and burnt gases (narrow-band cK). The original integration of the Quasi Monte Carlo method within the YALES2 framework, thanks to the CWIPI coupling library developed in ONERA, provides a high-fidelity representation of heat transfer inside the combustor. Furthermore, QMC's flexibility and scalability allow precise control over error, facilitating a balanced approach between computational cost and accuracy [5].

Numerical results will be benchmarked against experimental data for the coupled and uncoupled simulations. By analyzing the combustor energy balance, the study will enhance the understanding of oxy-combustion flame stabilization under realistic effects of thermal radiation.

References

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