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Numerical simulations of large-scale H_2 enriched industrial burners using the Lattice-Boltzmann method.

Uday CHIKKABIKKODU[1]*, Jose-Luis ANDRES LOPEZ[1], Song ZHAO[1],
Jean-Louis CONSALVI[2], Pierre BOIVIN [1]
*Lead presenter: uday.chikkabikkodu@univ-amu.fr
[1] Aix Marseille Univ, CNRS, Centrale Med, M2P2, Marseille, France.
[2] Aix Marseille Univ, CNRS, IUSTI, Marseille, France.

The continued reliance on fossil fuels, particularly natural gas, has driven atmospheric CO_2 levels higher, and intensified the urgency of decarbonising industrial energy use. Hydrogen and ammonia offer pathways to deliver net-zero emissions while maintaining the reliability industries demand. However, the existing infrastructure and energy demands aren't built to accommodate an abrupt, full-scale transition to hydrogen-powered systems. They must evolve gradually, using efficient, low-emission combustion systems that blend hydrogen with natural gas to balance performance and NOx emissions.

In this work, we present large-eddy simulations of a large-scale industrial burner (6 m in length), operating with methane-hydrogen blends, using the Lattice Boltzmann method (LBM) [1]. The burner employs partially premixed combustion technology, and features a central fuel pilot and annular premixed fuel-air mixture injection through a perforated cylindrical holder into the combustion chamber.

Simulations were carried out for three different fuel blends. Sub-grid combustion dynamics are modelled using a thickened flame approach [2], radiative heat transfer with the P1-WSGG model [3], and a low-Mach number approximation was used to reduce computational cost. A single-step chemistry [4] is employed, with NOx formation evaluated in post-processing using the frozen flow field.

Results were compared with experimental in-flame and radiation measurements. Good agreement between experiments and simulations have been obtained, particularly for O_2 and NOx evolutions, and radiative fluxes. Finally, by benchmarking against results obtained from RANS computations, we demonstrate that LES-LBM provides both the accuracy and computational feasibility needed to guide the design of next-generation, low-emission industrial burners.

References

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