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Numerical investigation of an oxy-methane sCO2 combustion system.

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Oxy-fuel supercritical carbon dioxide (sCO_2) power cycles represent a promising technological solution for the sustainable utilization of hydrocarbon fuels, enabling near-complete carbon capture and supporting the achievement of carbon neutrality. In this context, in the Allam cycle [1], carbon dioxide under supercritical conditions serves as the working fluid, allowing for more compact components and offering the potential to increase the thermal efficiency. Within the high-pressure combustor, methane is burned using a CO_2-O_2 mixture, and a stream of recycled sCO_2 is employed for cooling purposes. The resulting extremely high operating pressure and the elevated CO_2 content pose several technical challenges, introducing a combustion scenario that remains relatively unexplored.

From a numerical perspective, the main challenges are associated with the choice of the strategy employed in the numerical modeling of the combustion process. Although a species transport model is inherently capable of capturing several factors as the multi-stream nature of the problem, the development of a reduced reaction mechanism to accurately describe the combustion process and the complex chemistry of hydrocarbons is necessary to limit the computational cost. In contrast, tabulated chemistry approaches enable the utilization of detailed reaction mechanisms, whereas an extension of the standard models is necessary to account for the presence of a third stream in addition to fuel and oxidizer.

The aim of this work is to investigate the stability of an oxy-methane combustion system in a CO_2 environment during the start-up phase within a single-burner industrial combustor. The study employs different chemistry and combustion models for high-fidelity LES simulations. In particular, an optimized reaction mechanism is developed for the operating conditions under investigation and validated using a canonical test case. Furthermore, the standard version of the Flamelet Generated Manifold model is extended to incorporate the effects of CO_2 dilution and manage the specific conditions of interest.

References

[1] R. Allam, M. R. Palmer, G. W. Brown, J. Fetvedt, D. Freed, H. Nomoto, M. Itoh, N. Okita, C. Jones, High efficiency and low cost of electricity generation from fossil fuels while eliminating atmospheric emissions, including carbon dioxide. Energy Procedia. 2013