Assessment of flamelet-tabulated approaches for LES analysis of swirl non-premixed flames

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Abstract

As of today, a substantial interest still revolves around the understanding of swirled turbulent flames of typical aero-engine combustors, despite the progresses of the last twenty years. Although a number of LES studies on flame stability, transitions into unsteady behavior and swirl induced vortex breakdown already exist on experimental configurations, less is established in terms of tabulated combustion modeling of unsteady effects such as localised extinction experienced by highly swirling flames. This contribution presents work-in-progress analysis on a hybrid swirl/bluff body burner [1] envisaging unconfined, turbulent, swirled flames at atmospheric pressure and providing simple yet well-defined boundary conditions [1]. Swirl is introduced into the primary air stream by three tangential inlets positioned up-stream of the burner exit plane. In the present work only part of the burner is considered as computational domain, restricting to the outlet of the injector element and to a portion of the surrounding environment. This choice is justified by the unconfined nature of the investigated flames and by previous studies on the selected configuration. As a consequence swirl is imposed as an inflow boundary condition. A validation of the proposed simplified setting is carried out in terms of averaged radial profiles of axial and tangential velocity, temperature and selected species for the cold case and for a methane/air swirled non-premixed flame with a geometric swirl number of 0.5 (denoted as SM1). Simulations are performed both with the multi-physics finite element code Alya [2] and with an in-house developed solver based on OpenFOAM [3], providing a comparison between steady and unsteady flamelet approaches. A good reproduction of the main flow field and flame characteristics is found for SM1 with the steady approach. Questions arise when the analysis is moved to SM2, where localized extinction phenomena downstream the first central recirculation zone are observed.

References

[1] P. A. M. Kalt et al., Proc. Combust. Inst. 29, 2002/pp. 1913–1919
[2] M. Vázquez at al. J. Comput. Sci. 14, 2016/pp. 15–27
[3] G. Indelicato et al. Int. J. Heat Mass Transf. 169-120913, 2021