Impact of a bluff-body design on dynamics of turbulent non-premixed hydrogen flame

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A conical bluff-body (B-B) is a typical element of injection systems in combustor chambers. Its role is to create recirculation regions enhancing fuel/oxidizer mixing process and stabilize the flame.[1] To have a larger control on its dynamics, swirlers are very often mounted in pipes and channels providing fuel and oxidizer. These elements, however, cause a significant pressure drop and increase of drag force, and thus, increase the power needed to supply assumed mass flow rates. Despite a substantial number of research devoted to B-B flames, relatively few concentrate on the optimization of the B-B shape[2,3]. In the present work, we consider a conical B-B with a star shape or wavy surface presented in Fig. 1 showing a computational configuration. We try to find the B-B shape ensuring assumed combustion characteristics (high level of mixing, low combustion temperature, stable lifted flame). The upper B-B surfaces are the same ($U_{\mathrm{bulk,oxy}} = \mathrm{const.}$) and the differences in the combustion characteristics steam from small turbulent structures generated on the B-B edges (see Q-parameter in Fig. 1) and their interplay with large Kelvin-Helmholtz type toroidal vortices.

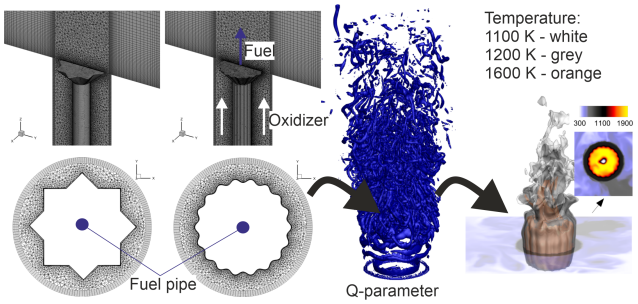

Figure 1: Computational configuration and sample results

We consider pure hydrogen as fuel and air as oxidizer. The research is performed by applying the Large Eddy Simulation method combined with the Eulerian stochastic field combustion model with a detailed chemical kinetics. Two numerical codes are used, ANSYS Fluent to model the flow inside a complex shape oxidizer duct, and an in-house high-order code SAILOR to precisely model the combustion dynamics in a combustor chamber. Figure 1 shows the Q-parameter and the temperature isosurfaces in the configuration with the wavy B-B. It can be seen that in the close vicinity of B-B the flow adapts to its shape. The oxidizer flowing in the valleys of the waviness, when it enters the combustion chamber, behaves as a bunch of separate streams causing a large amount of oxidizer to flow towards the combustion zone. Thus, the combustion zone becomes leaner but an enhanced mixing ensures a stable flame position.

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[2]Bagheri, Hosseini, Wahid, Appl. Therm. Eng., 67:266-272 (2014)
[3]Fan et al., Appl. Therm. Eng., 62:13-19 (2014)