Scalar mixing uncertainty effect on the predictions of reactor-based combustion models: application to a lifted methane/air jet flame

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Abstract

This work's purpose is to quantify the predictive uncertainty in RANS simulation of a non-premixed lifted flame due to uncertainty in the scalar dissipation rate transport equation model parameters. Polynomial Chaos Expansion is employed to create the surrogate model of the uncertain response to determine the uncertainty propagation and the global sensitivity analysis of the effect of such parameters on the quantities of interest (QoIs). This approach is applied on a lifted methane-air jet flame in vitiated coflow, already experimentally investigated by Cabra et al [1]. The results show the effectiveness of the approach to provide predictions with estimates of uncertainty. It is shown that the the uncertainty in the mixture fraction and temperature is negligible as long as only pure mixing happens, then it becomes significant in the regions where ignition begins, starting from $z/D = 30$ (fig. 1).

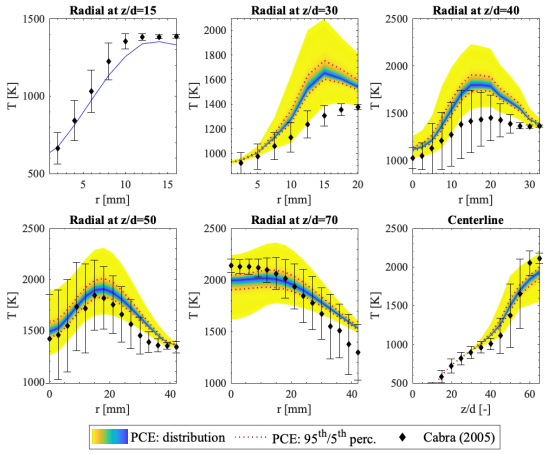

Figure 1: Radial and axial profiles of favre-averaged temperature PDFs. Red dots indicate $95^{th}/5^{th}$ percentiles. Black dots and bars represent experimental values and their measured RMS.

Of the four parameters considered C_{D1}, C_{D2}, C_{P1} and C_{P2}, main and total effect sensitivity indices shows that the largest contribution to the uncertainty in QoIs is given by the two dissipation parameters C_{D1} and C_{D2}, while the production parameter C_{P2} has almost negligible impact on the predictions (fig. 2).

Lastly, the surrogate models are used to determine an optimum set of parameters that minimizes the distance with the experimental measures, leading

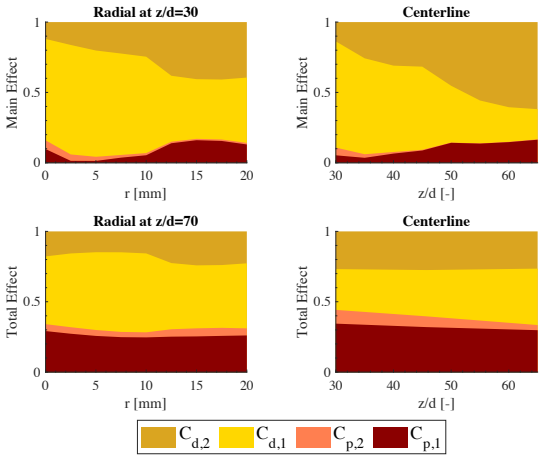

Figure 2: Main and total effect sensitivity indices for the favre-averaged temperature at $z/D = 70$ and centerline.

to improved predictions of the QoIs, as shown in fig. 3

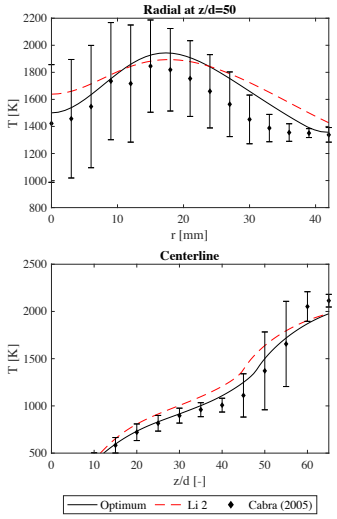

Figure 3: Radial $z/D = 50$ and centerline predicted temperature profile obtained with the optimum set of parameters (black), with the *Li 2* set (red), and experimental measurements (black diamonds) with their RMS.

References

[1] R. Cabra, J.-Y. Chen, R. Dibble, A. Karpetis, R. Bar- low, Lifted methaneair jet flames in a vitiated coflow, Combustion and Flame 143 (4) (2005) 491506