Combustion Group — overview

The combustion group at the 2018 CTR Summer Program consisted of seven research teams, covering a wide range of topics pertaining to fundamental combustion analysis, model development, multiphase flows, and data analysis. To foster close discussions, two overarching research topics were identified: (i) combustion physics and modeling and (ii) uncertainty quantification and data analysis. To guide to reader through the research briefs, an overview of all research topics and accomplishments is given.

The project by MacArt & Mueller was concerned with examining subgrid models for the prediction of turbulent scalar fluxes in premixed flames for conditions spanning low- and high-Karlovitz-number. Three different models were considered through *a-priori* and *a-posteriori* analyses, showing that low-Karlovitz-number conditions pose significant challenges for current models in accurately predicting dilation-induced turbulent production at small scales.

Aboulhasanzadeh & Mohseni revised the limits of the Euler equations and derived a set of observable equations to regularize conservation laws. The formalism was extended to two-phase and reacting flows and applications to challenging shock/bubble-interaction problems, and one-dimensional unsteady detonation systems showed good success. Since this approach introduces a regularization at the level of a partial differential equation, it holds promise for other applications.

Duwig *et al.* analyzed a direct numerical simulation (DNS) database of interface-resolved evaporating droplets by considering of four-way coupling between droplets and its turbulent environment. Direct comparisons of large-eddy simulation (LES) results with a Lagrangian particle tracking (LPT) method showed significant deficiencies of point-particle methods in captured droplet dynamics. These deficiencies could be attributed to finite-size effects and bulk-flow interaction, demonstrating the need for further research in improving commonly employed LPT methods.

Yu *et al.* employed data assimilation to improve the predictive capability of low-order models in capturing the transient flame dynamics in premixed flames. To this end, an ensemble Kalman filter was employed for state and parameter estimations in the context of a computational twin experiment and by assimilating data from a DNS into a low-order level-set model. Interestingly, it was shown that the assimilation improves the qualitative prediction of the flame dynamics to the limit of saturating the model fidelity due to the lack of underlying physics that is not contained in the low-order model.

Silva *et al.* utilized generalized chaos expansion for quantifying uncertainties in thermoacoustic models. This formulation enables the consideration of state variables, boundary conditions, and model parameters as stochastic variables, providing a probabilistic description of uncertainties in thermoacoustic systems. The method was applied to problems of different complexity, demonstrating its merit as an affordable technique for evaluating global sensitivity analysis.

Lapeyre *et al.* explored the prospect of using deep learning as a means for the construction of models for flame-surface density in turbulent premixed flames. To this end, a convolutional neural network was trained from DNS data. Evaluations of this network-model in *a-priori* and *a-posteriori* tests showed promising results, and limitations in its generalization and application to other configurations were identified.

Research by Edoh & Gallagher addressed the analysis of coupling effects between numerical discretization and filtering on numerical errors in LES. To this end, different spatial discretization schemes were examined in the context of explicitly filtered LES by employing a so-called tandem DNS, and strategies for mitigating the propagation and amplification of numerical errors were developed. It was concluded that high-order spatial discretization and an increasing filter-to-grid ratio for explicitly filtered LES provide opportunities for the effective mitigation of numerical errors.

On behalf of the entire combustion group, I thank all participants for many stimulating discussions and engaging conversations during the 2018 CTR Summer Program.

Matthias Ihme