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Investigation of Chemiluminescence in Technical Combustion Systems Using LES and Ray Tracing

Motivation

In the recent years, the numerical simulation of turbulent flows have become popular in optimization of technical systems. Especially, Large Eddy Simulation (LES), which is accepted as a promising tool, has made a considerable progress. The restricted ability of Reynolds Averaged Navier Stokes (RANS) approaches to predict unsteady flows and the immense computer resource requirement of Direct Numerical Simulation (DNS) encouraged this tendency of development. In LES, the larger three-dimensional unsteady turbulent motions are directly represented, whereas the effects of the small scale motions are modelled. Therefore, it is a compromise between DNS and RANS in complexity and computational effort. The main motivation of this working group is to develop models for the prediction of Excited-State Species in Technical Combustion Systems using LES. Several models are described in literature for the prediction of the major species in premixed and diffusion flames whereas a model for the prediction of Excited-State Species are not introduced in both types of flames yet. Additionally, possible relations between the local concentrations of the above mentioned species and heat release are investigated.
Another important motivation of the working group is to simulate an experiment by post-processing using the LES data. Laser and signal beam paths transit different zones of a turbulent flame, during which extinction and beam steering happens. Statistical information of ray deviation and extinction derived through this study will be used to shift the validation interface between LES and experimental results.

Method

To predict the excited-state species of the diffusion flames the well-known steady flamelet approach based on the look-up tables including the one dimensional laminar flamelets at different strain rates are used. To make use of the previously gained experience in EKT the unconfined hydrogen jet flame configuration H3 is used for this investigation.
For the modelling of the premixed flames a flamelet model combined with a classical G-equation approach is used. The excited state species concentration distributions of the one dimensional laminar flamelets are pre-integrated and tabulated for different equivalence ratios and strain rates. These pre-integrated values can easily be picked up for each computational LES cell from the look up tables since the corresponding values for strain rate and equivalence ratio are available through the simulation. To validate the model, an unconfined swirl burner (Tecflam) is simulated.
Finally, the predicted LES data is used to simulate a ray from the emitting position up to the detector. The results can be presented in a probability density functions which show the ray deviation in different directions.

The G=0 illustrates the flame front where the colour represents the equivalence ratio having its maximum value at inflow (=0.833)