Hessisches Kompetenzzentrum
für Hochleistungsrechnen

Development and Application of Numerical Methods for the Simulation of Technical Premixed Combustion Systems



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Project Areas
Heat Energy Technology, Thermal Machines, Fluid Mechanics

Clusters
Lichtenberg Cluster Darmstadt

Software
FASTEST

Institute
Institute for Energy and Power Plant Technology

University
Technische Universität Darmstadt

Introduction

The accurate prediction of combustion processes requires to compute the flow, the concentration, and the chemical reaction. For the two former, standard Large Eddy Simulation (LES) techniques are applied with reasonable accuracy while the latter is object of this project. Specifically the chemical reaction evolves on scales that cannot be resolved. Furthermore, the number of species involved is very large and interact in a stiffly coupled system. Accordingly, methods are being developed to reduce the complexity of the reaction mechanism as well as to capture the remaining, reduced system on typical LES meshes. Within this project a continuous development of a numerical method developed at our institute is conducted.

Methods

The method represents an overall approach to apply all of these mentioned steps enabling the simulation of complex, realistic devices while still preserving a sufficient accuracy of the chemistry. Within this project generic configurations are considered while the methods will be applied in realistic aero-engine chambers of our project partner Rolls-Royce plc. Specifically the last period dealt with a more accurate source term treatment in the numerical discretization to reduce the modeling error caused by limited spatial resolution. Accordingly, significant portions of the work contained simple test cases

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where a detailed verification is possible.

The required reference solutions were constructed on extremely fine meshes and the models performance was assess on corresponding coarser meshes with grid sizes of practical relevance. In this regard, the tasks associated with high performance computing was given by the verification simulations on rather low geometrical and physical complexity, mostly in one-or two-dimensional domains. The high computing demand here results from a large number of runs required (often up to hundreds) and the fine mesh reference solution partially requiring millions of cells also in the two-dimensional setup.

Results

The scientific results mostly confirmed a good proceeding of the method. In the laminar situations a significantly increased accuracy could be obtained for a given mesh with the new implementations. The one-dimensional studies showed, that grid dependent error can be shifted towards larger grid sizes which will reduce the modeling requirement in the turbulent case. this could be confirmed by two-dimensional test-cases with artificial turbulence. The first runs of three-dimensional complex cases of the method were also possible, but also showed a critical interaction of the discretization with the combustion model in certain physical circumstances which requires further development.

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