Evaluation of OpenFOAM for unsteady simulations of gas turbine combustion systems

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For the development of gas turbine combustion systems CFD methods with predictive capabilities are of significant interest. Steady state RANS methods are considered to be adequate only for flow problems, where turbulence is isotropic and coherent structures as well as acoustic waves are not of relevance. In typical gas turbine combustion systems, flame stabilization is achieved by swirl induced vortex break-down. In swirling flows turbulence is not isotropic. Depending on the swirl number, coherent structures exist. Finally, pressure oscillations can occur, that cause velocity fluctuations of similar magnitude as turbulent fluctuations. Thus, unsteady modeling approaches which resolve large scale turbulence as well as coherent structures appear promising. Furthermore, acoustic phenomena can be resolved using sufficient small time steps in a compressible simulation.

A brief investigation has demonstrated that compressible simulations with acoustic CFL numbers around one can be performed with OpenFOAM vastly more efficient than with the commercial CFD-code CFX. Therefore, a validation study was performed using the OpenFOAM Xoodles solver. A generic, premixed, enclosed swirl flame is used as a test case. For this combustor experimental data regarding the velocity field, the temperature field as well as visualizations of the instantaneous flame structure from OH-PLIF are available. In general, very good agreement between experiment and simulation is observed.

However, during the evaluation of OpenFOAM several difficulties were encountered. Adequate consideration of effects of dissociation on flame temperature was found to be difficult to achieve with the existing implementation of the Shvab-Zel'dovich formalism. For unsteady compressible simulations, the acoustic properties of the boundary conditions are of importance. Approaches to obtain useful results with the existing code as well as alternative approaches are discussed.