LES Investigation of a Central Strut Injector with Perpendicular Injection for Scramjet Applications

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5th EUCASS 2013
July 1-5, Munich, Germany

Introduction

We present results from an implicit large-eddy simulation (LES) of jet mixing for a strut injector in a scramjet combustion engine. The simulation's focus is the cold mixing of the ejected test gas carbon dioxide (CO_2) with the surrounding supersonic air flow. The subgrid-scale turbulence model for this simulation is provided by the compressible Adaptive Local Deconvolution Method (ALDM) [1]. Results are compared to experimental data obtained by M. Gurtner and D. Paukner [2], which will be presented in a seperate talk.

This study aims at the correct reproduction of the air flow in the test section as well as the mixing process of the CO_2 with the air crossflow using the formerly mentioned, detailed simulation technique. Time averaged statistical data from the simulation will be compared to schlieren pictures taken from the experiment [2]. These optical measurements will also be used to investigate and validate the simulated penetration depth of the injected test gas.

Numerical method

The compressible Navier Stokes equations are solved on an adaptive Cartesian grid, using an explicit 3rd order accurate Runge-Kutta time-integration scheme and a finite-volume spatial discretization. The convective flux is discretized by the compressible Adaptive Local Deconvolution Method (ALDM) of S. Hickel [1], which also provides the subgrid-scale (SGS) turbulence model. The fully conservative immersed boundary technique of

M. Grilli et al. [3] is employed to represent the wedge and circular geometries of the strut injector and jet nozzle on the Cartesian grid.
Chapman Enskog mixing rules according to B. Poling [4] for viscosity and species diffusion are used. Enthalpy diffusion (see A. Cook [5]) is taken into account to calculate correct mixture properties of gases with different molecular weights. Additionally, the temperature dependent heat capacity of the mixture is modeled by NASA polynomials.

Computational setup

The experimental setup is shown in Fig. 1 by a CAD drawing with a highlighted volume which is the simulated part of the test chamber. To reduce computational costs only a box with reduced depth, containing one injection hole, and periodic sidewalls is considered. The upper chamber wall is modeled using a slip wall. Figure 2 shows the geometry of the computational domain together with the applied boundary conditions.

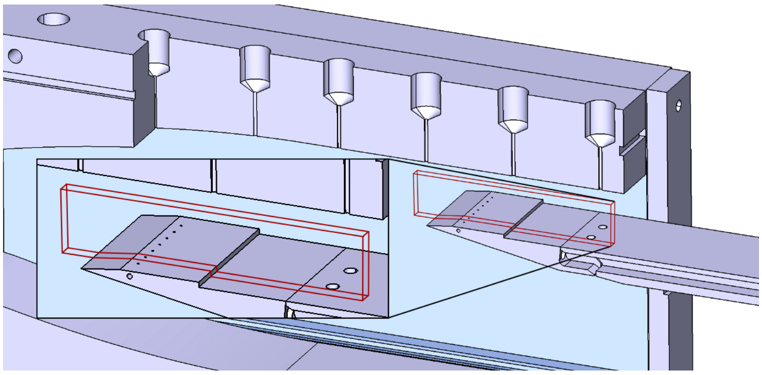

Figure 1: CAD drawing of the experimental facility. Red: computational domain for this study.

Free stream and injection conditions are matched to the experimental data in reference [2]. The incoming air flow has a free stream Mach number of $M_{air,\infty} = 2.0$, and a total temperature and pressure of $T_{0,air,\infty} = 290K$ and $p_{0,air,\infty} = 8bar$ respectively. For the CO_2 injection boundary condition a chamber temperature of $T_{0,jet,\infty} = 290K$ and a selected pressure from the experimental study [2] will be chosen.

Results

We will present a comprehensive statistical analysis of the flow field above and downstream of the strut injector. LES results will be compared with RANS results of [2] and

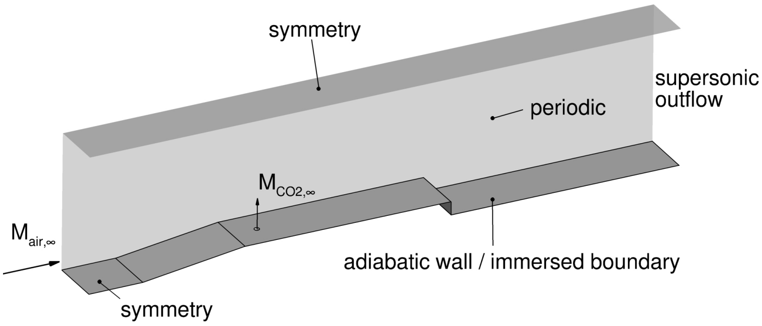

Figure 2: Geometry and boundary conditions for the LES computational domain.

validated against experimental wall pressure measurements and schlieren visualizations of the same reference.

References

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