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SUBSONIC SLANTED CAVITY COMBUSTOR SIMULATION WITH A DISCONTINUOUS SPECTRAL ELEMENT METHOD

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While high order methods are desired in order to accurately capture the small scale mixing effects in reacting flows, the challenge is to develop and implement such methods for complex geometries. For over a decade, our group has been engaged in the development of a high order, Discontinuous Spectral Element Method (DSEM) code [1–3] for simulation of compressible Navier-Stokes equations in complex geometries. In the present work, DSEM is modified by adding the appropriate components to solve for scalar transport equations, with species mass fractions as passive scalars, in order to simulate the chemical reaction.

Dealing with discontinuous solution at element interfaces in DSEM is a challenge that is met by patching the fluxes at mortars thus making them continuous on the interfaces. The patching is performed using the Lax-Friedrichs numerical flux for scalars, whereas a generalized Riemann solver is used for the Navier-Stokes equations. Implementing Lax-Friedrichs numerical flux to patch passive scalars in DSEM is one of the main objectives of this work, which has been successfully accomplished.

First, to validate the implementation of the reaction source term, a simulation is conducted in a well-stirred, constant volume combustor for a single step global reaction of hydrogen with air $H_2+\frac{1}{2}(O_2+3.76N_2) \rightarrow H_2O+\frac{3.76}{2}N_2$. The results of this simulation are compared with the results from the same case simulated with *CHEMKIN* and excellent agreement is observed.

Next, the method is implemented to simulate a subsonic reacting flow in a slanted cavity combustor (Fig. 1), as an early stage towards the development of a code for simulation of turbulent combustion in supersonic flows. The geometry used for this simulation is a simplified version of the scramjet engine with gaseous fuel injectors at the downstream side of the cavity. This simulation also demonstrates the capability of the method to handle complex geometries.

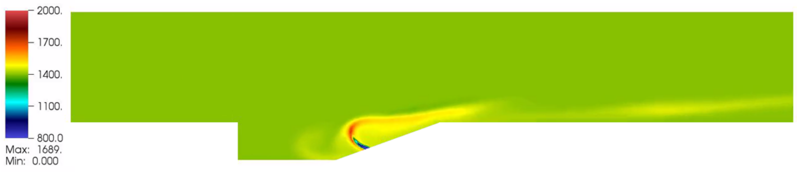

Figure 1: Temperature variation in a subsonic reacting flow in a slanted cavity combustor with fuel injector

In order to capture the small-scale effects of the fuel injector, a locally refined grid is needed. A computationally efficient type of such grids has been used in this work as shown in Fig. 2. This type of grid contains nodes which have five or three connections instead of four which is the case in regular grids. Making the DSEM code compatible with such a grid and node configuration is one of the challenges encountered in this work.

The effects of various parameters, such as the injector angle, flow rate, and equivalence ratio on the flow pattern and the reaction will be discussed in detail. The results will be also used for physical understanding of mixing and reaction in this type of combustors.

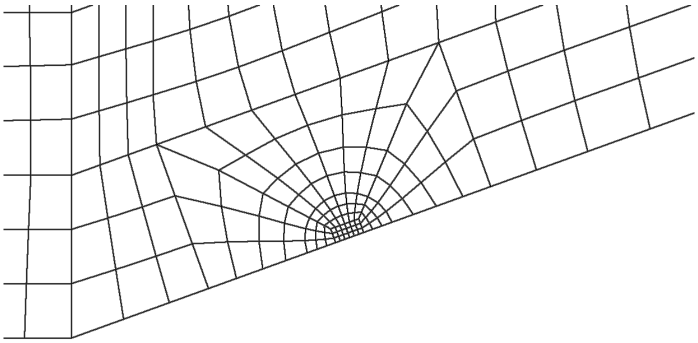

Figure 2: Locally refined grid used for the injector

As a long term plan, the DSEM code is being enhanced with the Filtered Mass Density Function (FMDF) method, which handles the reaction part, to simulate supersonic turbulent reactive flows. The results from the reactive flow simulations using scalar transport equations, presented in this work, will be used to validate the DSEM-FMDF code.

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