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SIMULATION OF SUPERSONIC COMBUSTION BASED ON VERY-LARGE EDDY SIMULATION METHOD

Abstract

The flow speed is quite high in supersonic combustion, which generally results in a high Reynolds number turbulent flow. Besides, the process involves complex flow physics, such as shock waves, supersonic boundary layers, mixing, combustion, etc. To understand those, high fidelity simulation method such as Large Eddy Simulation (LES) is generally preferred. However, application of LES for supersonic combustion is still limited as the computation cost is extremely high for such a high Reynolds number flow. The present study aims to develop a high-fidelity method for simulation of supersonic combustion with relative lower computation cost compared with LES, i.e. Very-Large Eddy Simulation (VLES) method.

VLES method is a recently-developed unified method (X. Han & S. Krajnovic, AIAA J., 2015) which can smoothly resolve the turbulence from RANS (Reynolds-Averaged Navier-Stokes) to DNS (Direct Numerical Simulation) based on the mesh resolution. That is, based on the mesh resolution, the method can resolve the maximum turbulence for that mesh resolution. Thus, it is quite suitable for supersonic flow and combustion simulation with fewer computational meshes. There are big differences between the VLES method and some popular hybrid RANS/LES methods (such as Detached Eddy Simulation, DES). In the core flow region away from the wall, hybrid RANS/LES method recovers to the tradition LES method, which requires the LES mesh resolution there, while for VLES method, it just needs the mesh fewer than LES mesh resolution there, that is, it performs in a VLES mode.

In the present study, the VLES method is further developed in the near wall region, which involves a delayed shift from RANS method to the VLES method, i.e. to protect the boundary layer a little bit more. It should be noted that the boundary layer is still mainly resolved in the VLES mode, rather than the RANS method. The developed VLES method is applied for two supersonic flow problems: shock/boundary layer interaction (25 degree ramp) and a supersonic combustor. The mesh is quite coarse for VLES compared with the LES mesh resolution in published papers (around 1/4 mesh cells are used). The results are compared with available experimental data and previous LES results. Both the mean and RMS flow fields are compared. It is found that the VLES method gives comparable predictions to LES method with much fewer meshes. The present study demonstrates the potential of VLES method for complex supersonic combustion applications.