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A STUDY OF COMPRESSIBILITY CORRECTIONS FOR K-OMEGA SST TURBULENCE MODEL IN HYPERSONIC FLOW APPLICATIONS

Abstract

In Hypersonic Flows, the hypothesis of Morkovin is no longer valid, and the fluctuation of density must be considered because of the strong compressibility and shock/boundary layer interactions. The traditional turbulence models have been developed for incompressible flows, which need to be corrected when they are applied in hypersonic flows.A numerical study of the Favre-averaged Navier-Stokes equations, employing k-ω shear-stress transport (SST) two-equation eddy viscosity turbulent model with compressibility corrections is presented. The additional terms of pressure-dilatation, pressure-work and dilatation-dissipation in the Favre-averaged equations are modeled to consider the compressible effects. In the present study, the cell-centered finite volume method based on a structured grid system is adopted, which divides the computational domain into non-overlapping hexahedra and directly utilizes the integral formulation of the control equations on each cell separately. The convective fluxes are calculated using AUSMPW+ scheme, and the MUSCL approach with van Albada limiter is employed to interpolate the left and right state values for higher order, and the viscous fluxes are computed by the Gauss theorem which is used to evaluate the first derivatives of the physical values. The implicit LU-SGS scheme is applied for time integration to accelerate the convergence of computations in steady flows. Three different cases of hypersonic flows are investigated, including 2D flat plate, compression ramp and 3D all-body hypersonic aircraft. The numerical results of surface pressure, heat transfer and velocity profiles are compared with experimental data to validate and demonstrate the capabilities of this method in hypersonic flows. There is good agreement between the experimental data and the numerical simulation results. In general, the k-ω SST model with compressibility corrections can satisfactorily predict the pressure distribution and only slightly overpredict the heat transfer, which is favorable in the design of aerodynamic configuration and thermal protection system for hypersonic vehicles.