Numerical Simulations of Underexpanded Supersonic Jet and Free Shear Layer Using WENO Schemes

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Abstract

Numerical simulations of the flowfield structures and properties of underexpanded supersonic jet and planar shear layer are performed by solving the time-dependent, compressible Euler equations. The numerical code uses the high-order weighted essentially non-oscillatory (WENO) finite difference schemes with the fifth-order-accurate for spatial discretization and the fourth-order-accurate Runge-Kutta scheme for time integration. The present predictions are compared with the available experimental data and other numerical results using different numerical schemes. Good agreements between the predicted and experimental data are achieved for both cases. The results show that the near-field region of the jet and shear layer is influenced by compressibility, which reduces turbulent mixing rates and suppresses vortex roll-up and pairings at high convective Mach number. Analyses of sound pressure level of the jet indicate that the broadband shock noise is generated from the shock cells and radiates in the direction of 40°-50° to the jet axis. Various forcing frequencies are applied at the inflow boundary to demonstrate mixing enhancement and shock cell destruction for the underexpanded jet. The computation of an underexpanded free shear layer indicates that the numerical turbulence model inherent with WENO algorithm can satisfactorily predict turbulence properties at a convective Mach number of 0.64 even without including subgrid-scale turbulence models.

Keyword：supersonic jet; free shear layer, WENO schemes; sound pressure level; mixing enhancement