ABSTRACT

Large eddy simulation (LES) of incompressible turbulent flow has been carried out for both single and parallel jets. The governing equations were discretized using second-order central difference scheme on a staggered grid arrangement. The dynamic Smagorinsky model (DSM) is used to resolve the subgrid scale stress tensor. A second-order time-accurate Adams-Bashforth fractional-step method was used for time integral, where the advective and diffusive terms were treated explicitly. The pressure Poisson equation has been solved by the conjugate gradient method in order to correct the pressure and velocity field. Multi-processing is used to reduce the computational time with the OpenMP extension of C++ code. For validation of the numerical code, the incompressible backward-facing step flow has been studied using large eddy simulation (LES) with dynamic Smagorinsky model (DSM) for Reynolds numbers of 100, 200, 397 and 648.

Later, detailed studies of three-dimensional spatially developing turbulent planar single and parallel jets have been carried out by large eddy simulation (LES). The jet Reynolds number is 4000 based on the inlet velocity and jet width. The transition from laminar to turbulent flow has been numerically identified and discussed in details. The evolution of vortex roll ups, their transportation and final disintegration to smaller vortices have been visualized by the plot of isosurface of Q criterion. The coherent structures in turbulent jets have been well demonstrated. The time series plots of λ_2 criterion shows the swirl and shear nature of the evolving vortices and their passage in the downstream. The time averaged velocity at far downstream ($x = 10$ and 15) shows a self-similarity behaviour where the flow has established a fully turbulent nature. The energy spectra are shown to exhibit the $-5/3$ power law. The proper orthogonal decomposition (POD) shows that 90% of the fluctuating kinetic energy is contained within the first 100 modes. The probability density function on the centerline ($y = 15$ and $z = 2.5$) for different x locations are plotted and the corresponding skewness and kurtosis values are reported for u,v, w and p. The Prandtl's mixing length, Taylor

microscale and the Kolmogorov length scales are shown along the lateral direction for different downstream locations. The autocorrelation in the longitudinal and in the transverse direction are seen to follow a similarity profile. Reynolds stress anisotropy tensor is calculated and the anisotropy invariant map (AIM) known as Lumley's triangle is presented and analyzed.

Keywords: planar free jet; planar free jet; LES; shearing and swirling vortices; proper orthogonal decomposition; coherent structures; mixing length; correlations.