Large Eddy Simulation of Channel and Jet Flows

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EXTENDED ABSTRACT

Turbulent flows are present in engineering applications. The objective of this research is to visualize turbulent flow fields to enhance understanding of the turbulent flows beyond the mathematical equation covered in the fluid mechanics class. To achieve the overall objectives Large Eddy Simulations are performed for channel and jet flows using a pseudo-spectral solver with dynamic Smagorinsky turbulence model.

Computational Fluid Dynamics Process and Numerical Methods

A general computational fluid dynamics process involves following aspects Geometry → Physics → Grid → Solution methods → Flow Analysis. The user defined parameters used in this study are: Reynolds number (3×10^4 and 1.3×10^4 for channel and jet flows, respectively); boundary conditions (periodic in streamwise and spanwise directions, and walls and zero-gradient in the normal direction for channel and jet flows, respectively); turbulence model which is dynamic Smagorinsky model; Grid sizes consisting of 400K, 1.3M and 4.8M points; number of processors; and solution iterations. The simulations are performed using a parallel pseudo-spectral solver, which uses Fast Fourier Transform in the spanwise and streamwise direction, Chebyshev polynomials in the normal direction, and MPI and OpenMP for parallelization.

Turbulent Flow Analysis

The flow analysis process involves visualization of: Diagnostic → 3D Solutions → 2D Spatially Averaged Solutions → Spatially and temporally averaged solutions. This study uses Tecplot for flow visualization. The diagnostic files, such as turbulent kinetic energy or wall shear stress (for channel) help track the flow development from the initial conditions to the fully developed turbulent simulations, and guide the solution iteration requirements. The visualization of the 3D volume solutions shows a random turbulent nature of the velocities and the small scale vortices in the flow. The 3D solutions show some organized structures such as the ejection events and hair-pin vortices near the wall for channel flows, and Kelvin-Helmholtz type instability for jet flows. The 2D spatially averaged solutions help assess the organized structures underneath the “random” turbulence. The analysis is performed for streamwise velocity mean (1st order), root-mean-square (RMS) of velocity fluctuations (2nd order statistics); skewness (3rd order statistics) and flatness (4th order statistics). The results show that the turbulence has well defined turbulent characteristics, such as: high RMS near the channel wall or inside the jet; higher skewness and flatness near the channel wall or jet edge and almost uniform values elsewhere. The spatially and temporally averaged solutions are compared with available direct numerical simulation results to validate the LES predictions. Further analysis is underway to explain the nature of the second and higher order statistics of the turbulent fluctuation, including evaluation of the effect of grid resolution on the turbulent flow predictions.