Seventh International Conference on Computational Fluid Dynamics (ICCFD7), Big Island, Hawaii, July 9-13, 2012

ICCFD7-2302

Direct numerical simulation of particle dispersion in a spatially developing turbulent boundary layer

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Abstract: We have performed direct numerical simulation (DNS) of a particle-laden spatially developing, zero-pressure-gradient turbulent boundary layer at $\mathrm{Re}_\theta = 1000 - 2750$. We computed the Lagrangian trajectories of fluid points and solid particles of three different Stokes numbers ($\mathrm{St} = 0.1$, 1, and 5). The particles were released in the computational domain from a line source at three different distances from the wall, in the viscous sublayer, the buffer layer, and the log-layer ($z^+_{inj} = 2$, 10, and 100). The fluid points mean-displacement obtained from the DNS is analyzed and compared to the theory of Batchelor (1964). Also, the time development of fluid point and solid particle mean-square displacement (or dispersion) and turbulent diffusivity are analyzed. Dispersion statistics are generally found to be strongly influenced by particle inertia. Such dependence is mostly caused by the particles tendency to preferentially concentrate in the viscous sublayer. Furthermore, for very long times (several integral timescales), the DNS results show that the streamwise dispersion of fluid points and particles with St= 0.1 is nearly $\propto t^{5/3}$, while that of particles with St= 1 and 5 is nearly $\propto t^{5/2}$. For all cases studied, the long-time wall-normal dispersion is nearly $\propto t$.

Keywords: Direct Numerical Simulation, Turbulent Boundary Layers, Particle-Laden Flows, Dispersion.