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NUMERICAL STUDY OF PARTICLE-LADEN TURBULENT CHANNEL FLOW

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The Numerical simulation has became a important tool to investigate complex phenomena taking place in multiphase turbulent flow. On the way of understanding particle-turbulence interactions two approaches are mainly used direct numerical simulation DNS and large eddy simulation LES. Accurate prediction of the behavior of particles in a turbulent flow can be obtained using Direct Numerical Simulation but this approach is the computational very expensive and restricts its application to a range of small Reynolds number values that are far from those found in practical application. To avoid this restriction, the LES approach with much coarser grid has been used. On the one hand, the flow-coarsening in LES facilitates the simulation of the primary features of complex turbulent flow at high Reynolds numbers. On the other hand, this flow-coarsening takes out much of the small-scale turbulent contributions to the motion of particles.

In this paper Eulerian-Lagrangian approach combined with Large Eddy Simulation (LES) of turbulent flow laden with large number of particles is investigated for three subgrid models and several Reynolds and Stokes numbers. The focus is on the accuracy of the subgrid models with respect to particle behavior, particle concentration and mean particle motion. Results are compare to DNS using different sub-filter models (Smagorinsky, Van Driest-Smagorinsky and the dynamic model). Comparison of the fluid and particle statistics shows in some detail the prediction of increased particle concentration near a solid wall through turbophoresis, as a function of the quality of the small-scale reconstruction of turbulent motion.

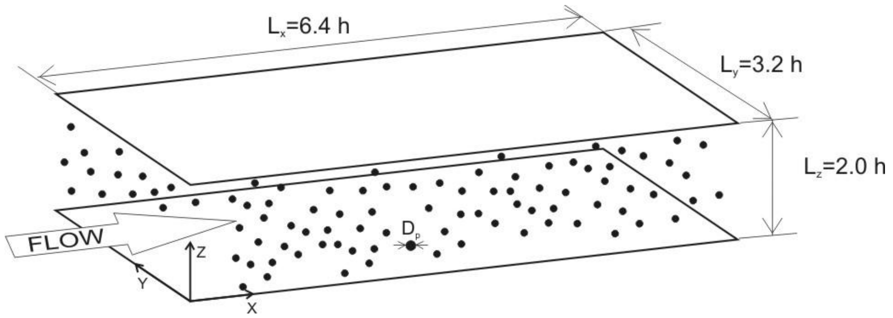

Figure 1. Computational domain of channel flow.

The presented simulation of wall-bounded turbulent particle-laden flow are based on the Euler-Lagrange point-particle approach. Particles are dispersed in a pressure-driven fluid flow, assumed to be incompressible and Newtonian. Restrict to very small volume fractions and assume that the size of the particles is considerably smaller than the local Kolmogorov length-scale in the turbulent flow. In such situations the particles have a negligible feedback coupling on the turbulence and the one-way coupling formulation for the particle phase can be employed. Simulations using presented models were performed in a computational domain as sketched in Fig. 1 with up to 64x64x64 control volumes for LES and up to 512x5126x256 in case of DNS. For the streamwise and spanwise directions the grid spacing is uniform, and for the wall normal direction a hyperbolic-tangent stretching has been used. The shear Reynolds number of the flow was up to Re_τ=590 based on the shear velocity and half channel height. In order to obtain good statistics for particles in these simulations we used $1.5*10^6$ particles for the DNS and up to one order less for LES.

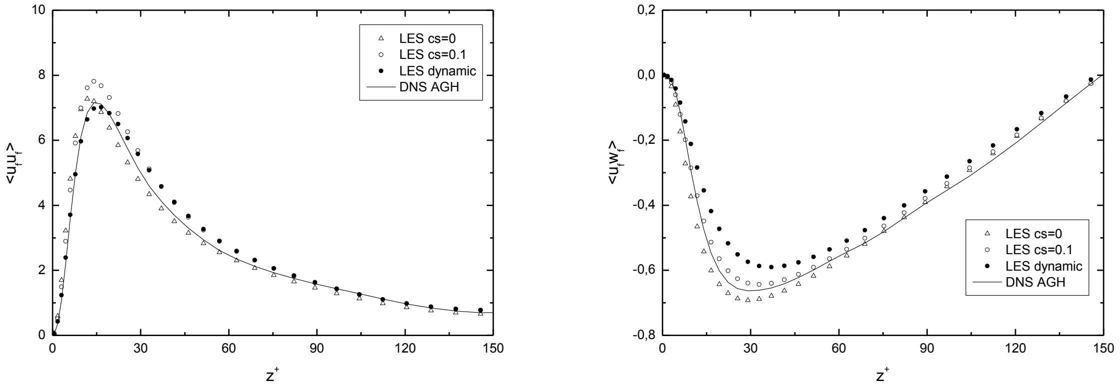

Figure 2. Fluid velocity fluctuations for the streamwise and streamwise-wall normal component comparing various sub-filter models with DNS results at Re_τ = 150.

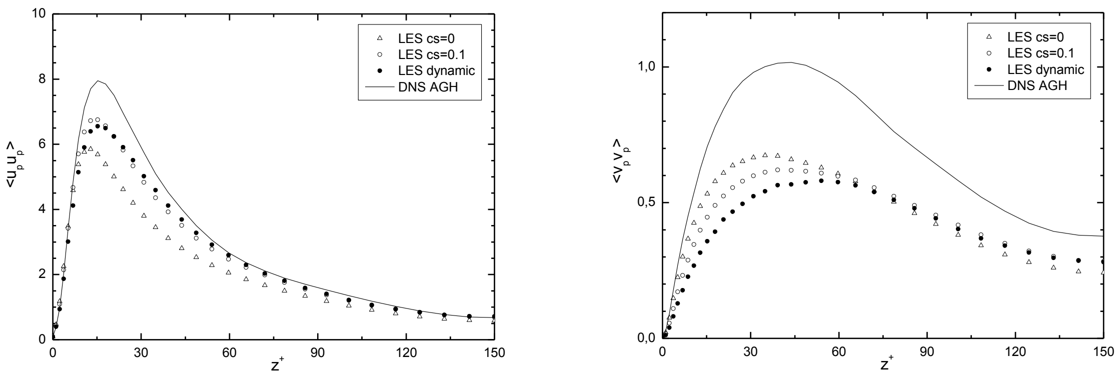

Figure 3. Particle velocity fluctuations $<u_p u_p>$ and $<v_p v_p>$ for the streamwise, ans spanwise comparing various sub-filter models with DNS at Re_τ=150 and for Stokes number St=1.

In Fig.2. and Fig.3. results of DNS with various LES are compare for the flow and particle velocity fluctuation, using the following labeling: LES with a value of CS implies the use of Smagorinsky's model at that C_S, with C_S=0 implies computations without SGS modeling, dynamic if the dynamic eddy-viscosity model is adopted. In all simulations we use the LES velocity field in the Stokes drag law to advance the particles.

In particular, even though the models reproduces more accurately results for the continuous phase in comparison to results obtained by DNS the properties of the dispersed phase computed using LES do not match the DNS results. The properties of the particles in terms of concentrations and velocity fluctuation profiles do not show large improvement with the use of different models for LES.

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