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Modulation of large-scale structures by neutrally buoyant and inertial finite-size particles in turbulent Couette flow

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Direct numerical simulations of particle laden flow are carried out with the Force-Coupling Method (FCM) to study the effect of finite-size particles on turbulent plane Couette flow (pCf). The Reynolds numbers considered were close to the laminar-turbulent transition, such that large scale rotational structures were well identified and relatively steady. Thereby, interaction of particles with coherent structures could be evidenced using particle-resolved numerical simulations with two Couette gap-to-particle size ratios (10 and 20), and with particle-to-fluid density ratio ranging from 0 to 5. Regarding the distribution of particles in the mixture flow, the concentration profiles (averaged in the homogeneous streamwise and spanwise directions) suggested a relatively homogeneous distribution of the particles across the Couette gap, resulting from the balance between hydrodynamic repulsive force from the walls, turbulent mixing and shear-induced diffusion. In the case of neutrally-buoyant particles, 2D snapshots of particle positions revealed higher (resp. lower) presence of particles in the sweep (resp. ejection) regions where they are trapped (resp. expelled) for a while. As for buoyant particles, the light ones ($\rho_p/\rho_f << 1$) were submitted, in addition to the above-mentioned interactions, to an inertia-induced lift force towards the center of large scale vortices. This leaded to an increase of the concentration profile in the Couette center. On the contrary, inertial particles ($\rho_p/\rho_f > 1$), were rather subject to an outward motion towards the walls, leading to small localized peaks in the concentration profile in that region. Time averaged profiles, in the wall-normal direction, of the mean flow and Reynolds stress components did not reveal significant difference between single phase and mixture flows at equivalent effective Reynolds number, except that the wall shear stress is higher in the two-phase flow. However temporal and modal analysis of flow fluctuations, suggested that particles had an impact on the regeneration cycle of turbulence. While the energy of large scale vortices (LSV) was unchanged by particles (only the rotation rate inside the vortex core was slightly reduced), the level of kinetic energy was increased over the range of intermediate wavenumbers for all considered particle sizes and densities. This is mainly due to flow perturbations induced by the non-deformability of the dispersed phase (finite size effect).

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