Turbulence modulation by finite-size spherical particles

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The present work studies the influence of the size of finite particles in particle-laden turbulence. The focus is on spherical particles in homogeneous and isotropic turbulence. The presence of solid particles introduces additional momentum interactions between the particles and the fluid, which results in modulation of the flow structures. When the suspension is non-dilute the carrier flow undergoes macroscopic changes and the particle-fluid interaction can not be neglected[1,2]. We investigate a two-dimensional parameter space, the particle size and the particle/fluid density, at a relatively large Reynolds number and in a non-dilute condition. The forcing is set to achieve a Reynolds number of $Re_\lambda \approx 400$ in the single-phase case, and the volume fraction is $\phi_v = 0.079$. The particle diameter D_p and the particle/fluid density ratio ρ_p/ρ_f are varied between $8 \leq D_p/\eta \leq 123$ (η is the Kolmogorov length scale) and $1.3 \leq \rho_p/\rho_f \leq 100$ (or $0.1 \leq \phi_M \leq 0.9$, with ϕ_M the mass fraction), to consider both light/heavy and large/small particles. We properly resolve the four-way fluid-solid coupling, using a numerical method based on a combination of direct numerical simulations and the immersed boundary method[3]. We show that the influence of the solid phase on the fluid phase changes with D_p/η and ρ_p/ρ_f. Depending on the turbulent forcing scheme, for intermediate sizes and large ρ_p/ρ_f the solid phase may drastically change the structure of the large-scale motions, and enhance the overall intensity of the velocity fluctuations (figure 1). A close look at the scale-by-scale energy transfer reveals that for small and heavy particles the classical energy cascade a lá Richardson is almost completely annihilated, and the energy injected at the largest scales is drained by the particles and directly transferred to the smallest dissipative scales.

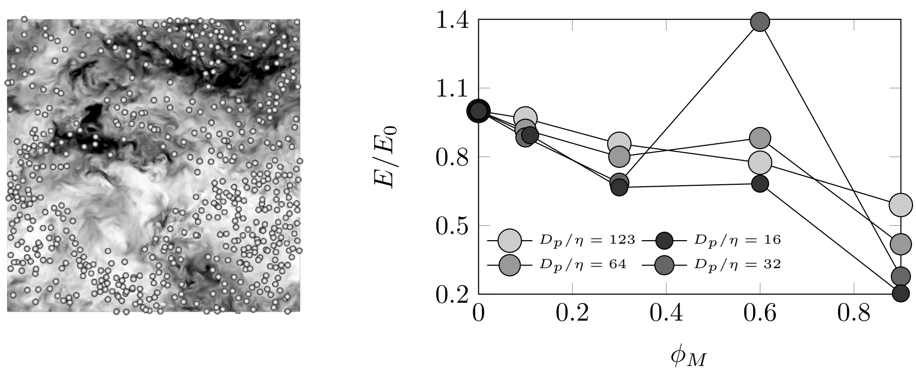

Figure 1: Left: View of the kinetic energy E for $D_p/\eta = 32$ and $\rho_p/\rho_f = 5$. Right: Dependence of E on the mass fraction for different particle sizes.

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[1] Balachandar and Eaton, *Annu. Rev. Fluid Mech.* **42**, 1 (2010).

[2] Brandt and Coletti, *Annu. Rev. Fluid Mech.* **54**, 1 (2022)

[3] Hori et al. *Comput Fluids* **236**, (2022).