Dense Particle Suspensions in Quasi-2D Turbulence

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Most previous studies concerned with dense particle suspensions have considered laminar (if not fully viscous) flows. On the other hand, most previous studies on particle-laden turbulence have focused on dilute concentrations. In fact, dense particles suspensions in turbulent regimes are frequently encountered in industrial and geophysical settings. Such a situation is highly challenging for numerical simulations, and very hard to characterize experimentally. Here we perform laboratory experiments on non-Brownian spherical particles of size O(1 mm) suspended in a quasi-two-dimensional (Q2D) flow, with concentrations from dilute to dense and underlying flow from laminar to turbulent. The latter is created by thin electro-magnetically driven layers of conducting fluids, with particles moving in a single layer at the interface. The Q2D nature of the system allows us to image and track the particles up to jamming conditions. We vary the particle size (which remains a small fraction of the forcing scale of the flow), the particle aerial fraction (up to 70%), the interfacial conditions (particles floating on the free surface or confined between two fluid layers), and the Reynolds number of the flow. Using particle tracking velocimetry, we characterize the tendency of the particles to form clusters, and their transport both from Lagrangian and Eulerian perspectives. The analysis of over 100 cases reveals the effect of three forces that mainly govern the dynamics: capillary interactions due to undulation of the contact line, drag force exerted by the surrounding fluid, and lubrication forces between particles in close proximity. Based on the balance of the involved forces and the experimental results, we propose a phase diagram that highlights distinct regimes of cluster formation and particle transport.

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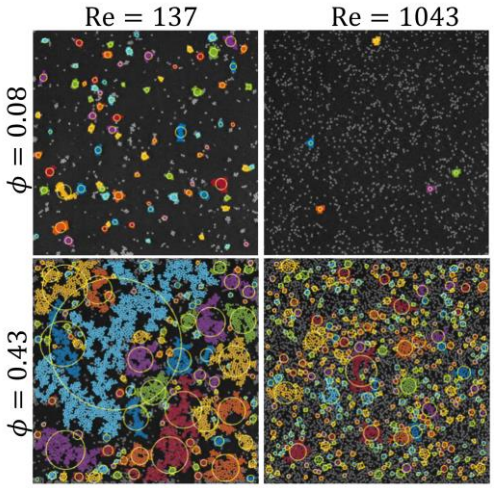

Figure 1: Four snapshots of clusters detected at different Re and surface fractions. Colors denote the clusters, while the imposed circles indicate their size and position.