Suspensions of finite-size rigid particles in laminar and turbulent flows

WALTER FORNARI

Academic Dissertation which, with due permission of the KTH Royal Institute of Technology, is submitted for public defence for the Degree of Doctor of Philosophy on Friday the 15th December 2017, at 10:15 a.m. in D3, Lindstedtsvägen 5, Stockholm.
Abstract

Dispersed multiphase flows occur in many biological, engineering and geophysical applications. Understanding the behavior of suspensions is a difficult task. In the present work, we numerically study the behavior of suspensions of finite-size rigid particles in different flows. Firstly, the sedimentation of spherical particles larger than the Taylor microscale in sustained homogeneous isotropic turbulence and quiescent fluid is investigated. The results show that the mean settling velocity is lower in an already turbulent flow than in a quiescent fluid. We also investigate the settling in quiescent fluid of oblate particles. We find that at low volume fractions the mean settling speed of the suspension is substantially larger than the terminal speed of an isolated oblate. Suspensions of finite-size spheres are also studied in turbulent channel flow. First, we change the solid volume and mass fractions, and the solid-to-fluid density ratio in an idealized scenario where gravity is neglected. Then we investigate the effects of polydispersity. It is found that the statistics are substantially altered by changes in volume fraction. We then consider suspensions of solid spheres in turbulent duct flows. We see that particles accumulate mostly at the corners or at the core depending on the volume fraction. Secondary motions are enhanced by increasing the volume fraction, until excluded volume effects are so strong that the turbulence activity is reduced. The inertial migration of spheres in laminar square duct flows is also investigated. We consider semi-dilute suspensions at different bulk Reynolds numbers and duct-to-particle size ratios. The highest particle concentration is found around the focusing points, except at very large volume fractions. Finally we study the rheology of confined dense suspensions of spheres in simple shear flow. We focus on the weakly inertial regime and show that the effective viscosity varies non-monotonically with increasing confinement.

Key Words
Suspensions, complex fluids, sedimentation, rheology, turbulence