Abstract

This thesis investigates particle-laden channel flows using point-particle direct numerical simulations, focusing on the effects of unstable thermal stratification and the contributions of various forces in the Maxey–Riley equation. Two key studies address gaps in the understanding of particle dynamics and preferential sampling behaviour in wall-bounded turbulent flows. The first study examines the dynamics of heavy particles in a mixed convection regime, where buoyancy and shear can combine to reorganize the flow into large-scale streamwise vortices. This reorganization significantly alters the topology of the flow, influencing particle distribution and preferential concentration. Thermal plumes impinging the near-wall region enhance vorticity-dominated structures, disrupting the typical balance between strain- and vorticity-dominated sampling by heavy particles. This leads to a distinctive asymmetric particle distribution near the walls, particularly when the particle relaxation time aligns with the characteristic timescale of large-scale coherent motions. The second investigation focuses on particles with small inertia and mass density comparable to the fluid density, called non-heavy particles, to explore the influence of the force contributions appearing in the Maxey–Riley equations. This analysis examines the statistical impact of the added-mass and the pressure drag forces on particle distribution within the channel. The results suggest that these contributions significantly reduce the effectiveness of the centrifuge mechanism in driving particle turbophoretic drift towards the walls. Resulting in a gradual decorrelation between particle concentration and both the strain-rate and the vorticity tensors, lower density ratios lead to a more uniform particle distribution, regardless of the Stokes number. The investigation further evaluates the relative magnitudes of the force contributions, including the Basset history force. Additionally, a novel scaling law for the pressure drag force in the case of small particles is proposed and validated against numerical evidence.