On the Euler-Lagrange Modeling of Particle-laden Turbulent Flows

By Pedram Pakseresht
Candidate for Doctor of Philosophy in Mechanical Engineering
Major Professor: Dr. Sourabh Apte

Abstract

Particle-laden turbulent flows, wherein many small size particles are dispersed in a fluid flow, are widely encountered in environmental phenomena and industrial applications. This thesis focuses on improving the modeling of such flows to better understand their underlying physics, make predictions without performing expensive experiments, and ultimately optimize the systems carrying such flows. These flows are typically modelled in a Euler-Lagrange (EL) approach, wherein the governing equations of the fluid phase are solved on a fixed Eulerian computational domain while particles are treated as Lagrangian points and tracked using the Newton’s second law of motion based on the fluid forces acting on them. Such a simplified point-particle model, however, could produce errors in capturing experimental observations or predicting analytical solutions. In this thesis, a general framework was developed to improve the state-of-the-art of the current EL approaches by (i) accounting for the mass displacement effect of particles on the flow and (ii) accurately computing the fluid forces acting on the particles. The former was quantified by performing investigations on a particle-laden jet flow under a wide range of parameters, while concerning the latter, a new physics-based model was introduced that is cost-efficient and applicable to all types of particle-laden flows with or without no-slip walls. Tests performed on canonical cases showed the accuracy and robustness of the newly developed model in reducing errors compared to the analytical solutions. The formulation was applied to a full-fledged particle-laden turbulent channel flow, for which the current EL approaches fail in capturing the experimental observations, while the developed model successfully predicted these observations.

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