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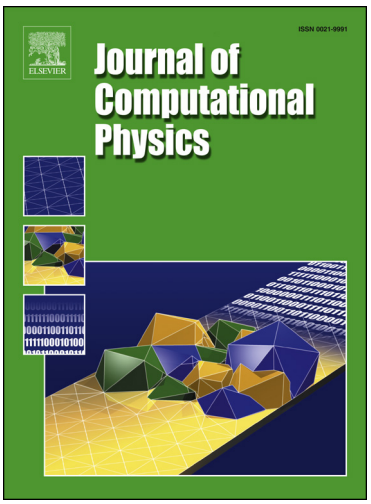

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G. Akiki, W.C. Moore, S. Balachandar

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PAIRWISE-INTERACTION EXTENDED POINT-PARTICLE MODEL FOR PARTICLE-LADEN FLOWS

G. Akiki, W. C. Moore and S. Balachandar
Department of Mechanical and Aerospace Engineering, University of Florida

In this work we consider the pairwise interaction extended point-particle (PIEP) model for Euler-Lagrange simulations of particle-laden flows. By accounting for the precise location of neighbors the PIEP model goes beyond local particle volume fraction, and distinguishes the influence of upstream, downstream and laterally located neighbors. The two main ingredients of the PIEP model are (i) the undisturbed flow at any particle is evaluated as a superposition of the macroscale flow and a microscale flow that is approximated as a pairwise superposition of perturbation fields induced by each of the neighboring particles, and (ii) the forces and torque on the particle are then calculated from the undisturbed flow using the Faxén form of the force relation. The computational efficiency of the standard Euler-Lagrange approach is retained, since the microscale perturbation fields induced by a neighbor are pre-computed and stored as PIEP maps. Here we extend the PIEP force model of Akiki et al (2017) with a corresponding torque model to systematically include the effect of perturbation fields induced by the neighbors in evaluating the net torque. Also, we use DNS results from a uniform flow over two stationary spheres to further improve the PIEP force and torque models. We then test the PIEP model in three different sedimentation problems and compare the results against corresponding DNS to assess the accuracy of the PIEP model and improvement over the standard point-particle approach. In the case of two sedimenting spheres in a quiescent ambient the PIEP model is shown to capture the drafting-kissing-tumbling process. In cases of 5 and 80 sedimenting spheres a good agreement is obtained between the PIEP simulation and the DNS. For all three simulations, the DEM-PIEP was able to recreate, to a good extent, the results from the DNS, while requiring only a negligible fraction of the numerical resources required by the fully-resolved DNS.

1. Introduction

Many numerical techniques are in use in the investigation of particle-laden flows. A popular numerical method is the fully-resolved Direct Numerical Simulation (DNS) whose chief advantage is that it is based on first-principles and, therefore, avoids the use of empirical closure models. However, its main downside is numerical cost which limits the number of particles that can be included in the simulations, as well as the particle Reynolds number. The number of particles in these simulations typically range from a single particle to a few thousand particles. Some of the larger resolved DNS were presented recently by Uhlmann and coworkers (2014, 2016) with tens of thousands of spheres. These simulations require enormous computational resources.

Another class of numerical methods for the simulation of particle-laden flows is the Euler-Lagrange point-particle approach. An Eulerian grid, much larger than the particle size, is used where the Navier-Stokes equations are solved. The hydrodynamic forces on the particles are then