Voidage and Fluid Speed Correction Algorithms for Improved Heat and Mass Transfer Predictions in Unresolved Particle Simulations

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ABSTRACT

Gas-particle flows are extensively used in chemical, petrochemical, and pharmaceutical industries, as well as energy applications. Simulations of industrial-scale processes are usually computationally expensive for both Eulerian and Lagrangian approaches. To make the simulation more affordable, coarse-grid simulation is widely adopted as an approach. Previous studies have developed constitutive "filtered" models [1-3] to account for the effect of unresolved fluctuations of the voidage and velocity field on momentum exchange coefficients. In our present study we explore an alternative strategy to improve the momentum, heat, and mass exchange rate predictions with a focus on dense systems.

Our initial grid sensitivity study of momentum and heat transfer rates in a fixed bed proves that the main source of error in coarse-grid simulations is the inaccurate prediction of the local voidage felt by individual particles. As a result, for various distributions of particles in the bed, we first attempt to map the voidage (and its gradient) available in a coarse grid simulation to the corresponding value in a fine-grid simulation. This is achieved through developing and testing various correction functions for the voidage field. We demonstrate that such a correction of the voidage in the packed bed can greatly improve the prediction of exchange coefficients. Most important, the correction increases the average exchange coefficient in certain situations. This feature is predicted by none of the currently available filtered models.

Afterwards, the developed correction function was implemented in CFDEM® [4]. Aiming at matching the drag force in coarse- and fine-grid simulations, a correction function for velocity is developed and implemented as well. The fidelity of the newly developed strategy is examined in a packed and a fluidized bed setup through a comparison of flow field properties, as well as the predicted exchange rates for momentum, heat, and mass.

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