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Original Research Paper

Study on a large-scale discrete element model for fine particles in a fluidized bed

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ABSTRACT

The discrete element method (DEM) is widely used to comprehend complicated phenomena such as gas–solid flows. This is because the DEM enables us to investigate the characteristics of the granular flow at the particle level. The DEM is a Lagrangian approach where each individual particle is calculated based on Newton's second law of motion. However, it is difficult to use the DEM to model industrial powder processes, where over a billion particles are dealt with, because the calculation cost becomes too expensive when the number of particles is huge. To solve this issue, we have developed a coarse grain model to simulate the non-cohesive particle behavior in large-scale powder systems. The coarse grain particle represents a group of original particles. Accordingly, the coarse grain model makes it possible to perform the simulations by using a smaller number of calculated particles than are physically present. As might be expected, handling of fine particles involving cohesive force is often required in industry. In the present study, we evolved the coarse grain model to simulate these fine particles. Numerical simulations were performed to show the adequacy of this model in a fluidized bed, which is a typical gas–solid flow situation. The results obtained from our model and for the original particle systems were compared in terms of the transient change of the bed height and pressure drop. The new model can simulate the original particle behavior accurately.

1. Introduction

Gas–solid two phase flows are often encountered in a variety of industrially important processes. Fluidized beds are typical gas–solid flow systems, and are frequently used in the chemical, environmental and energy industries due to their favorable characteristics. The flow in fluidized beds is too complicated to fully characterize experimentally. Numerical simulation might contribute to understanding the complex phenomena. Gas–solid flows have often been simulated by combining the discrete element method (DEM) [1] with computational fluid dynamics (CFD) [2,3]. The DEM is a Lagrangian approach where each individual particle is calculated based on Newton's second law of motion, and is used to compute the solid particle behavior, enabling the granular flow characteristics to be investigated at the particle level. Since the development of the DEM–CFD method, various gas–solid flows have been computed, e.g., spouted beds [2,4], bubbling fluidized beds [5,6], circulating fluidized beds [7], pneumatic conveying [8], packing [9], wet ball milling [10], etc. As might be expected, research into cohesive particle behavior in gas–solid flows is crucial from the viewpoints of science and engineering. The DEM easily takes into account the effects of cohesive forces. In previous reports, numerical studies have taken into account various interparticle forces, e.g., van der Waals [11–13], liquid bridge [14], electrostatic forces [15], etc.

As described above, although the numerical approach is promising for understanding granular flows, the DEM has a critical problem. Namely, the number of particles that can be calculated is restricted because of excessive calculation cost. The simulation of larger-scale systems was performed by introducing the parallel computation technique [16,17]. However, the number of particles was still much smaller than that required in industry where typically over a billion particles are dealt with. The number of calculated particles that could be handled in recent studies was at most a few hundreds of thousands, (approximately a spoonful of sugar), even using the latest PCs or PC clusters. This is because DEM simulations using an excessive number of particles cannot be completed within a practical time period. Consequently, the existing DEM is difficult to apply to industrial systems.

A new large-scale DEM simulation model, referred to as the coarse grain model [18,19] was proposed to solve this issue. A coarse grain particle represents a group of original particles. Therefore, a large-scale DEM simulation can be performed by using a smaller number of calculated particles than is physically present. Originally, the coarse grain model was applied to simulating

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