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LARGE-SCALE DISCRETE ELEMENT MODELING IN GAS-SOLID FLOWS

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ABSTRACT

Discrete element method is an effective approach to evaluate granular flows, whereas it is hardly used in investigating the design and investigation of the operational conditions in industries. This is due to the fact that the number of particles is restricted by the limit of computer memories. By using the latest PC, the number of calculated particles is hundreds of thousand which is equivalent to a spoonful of sugar. Consequently the original discrete element method is difficult to be applied to the large-scale systems, where a large number of particles are dealt with. In this study, a new discrete element modeling for large-scale particle systems is proposed where a modeled particle whose size is larger than the original particle is analyzed instead of a crowd of original particles. This is named coarse grain model. The coarse grain model is applied to a three-dimensional plug flow in a horizontal pipeline. The plug length, the cycle and stationary layer area occupation are compared between the modeled coarse particle systems and the original particle system. The coarse grain model can simulate the original particle system adequately.

OVERVIEW OF COARSE GRAIN MODEL

You may have a question that the DEM simulation can be performed by using large-sized particles simply. The answer is “No”. This is because the drag force acting on particles depends on the particle size. Besides, dissipation energy due to collision is not in agreement between the large-sized particle system and the small-sized one.

A modeled coarse particle is used by representing a group of original particles in this model. The coarse particle moves by taking into account the particle-particle contact force, the drag force and the external force. The contact force acting on the coarse particle is modeled under the assumption that kinetic energy of the calculated coarse particle agrees with that of the original particles and it is evaluated by using spring, dash-pot and friction slider like the DEM. The drag force is estimated by an inter-phase momentum transfer coefficient whose parameters based on the original physical properties times the relative velocity between solid and gas.

NUMERICAL SIMULATION

Periodic condition was applied in the numerical example. The diameter and the length of the pipeline were 0.05 m and 0.8 m, respectively. The particle size was 2.0 mm and the density was 1000

kg/m^3. Air was injected from the left side of the pipeline with 2.0 m/s. Three cases of simulation were performed to verify the coarse grain model. In Case 1, the simulation was performed in original particle system. Calculations using the coarse grain model were carried out to simulate the original particle system in Case 2 and Case 3. The modeled particles whose size were twice and triple as large as the original size were used in Case 2 and Case 3.

Figure 1 shows typical snapshots of plug conveying simulations in quasi-steady state. The snapshots were listed at 0.1 sec intervals. The plug feature and fluidity were in qualitative agreement with those of the past studies [1, 2]. In the simulation results where the coarse grain model was applied, plugs were created like the original particle system. Moreover the plug periodicity of the coarse particle systems was almost the same as that of original system. On the other hand, the plug was not created by using the same size of calculated particle without the coarse grain model, though this result was not shown in the paper.

The simulation results were compared with an experiment. All the simulation results satisfied the relationship between the stationary layer area occupation and the plug velocity which was shown by Konrad and Davidson [3] experimentally.

These results show that the coarse grain model can simulate the original particle system precisely.

CONCLUSION

A coarse grain model in Discrete Element Method (DEM) simulation for large-scale systems was developed and its verification was performed in a pneumatic conveying system. The following results were obtained.

1) The plug length and the periodic motion were in good agreement between the modeled coarse particle systems and the original particle one.

2) The simulation using the coarse grain model satisfied the relationship between the stationary layer area occupation and the plug velocity along with that of the original particle system.

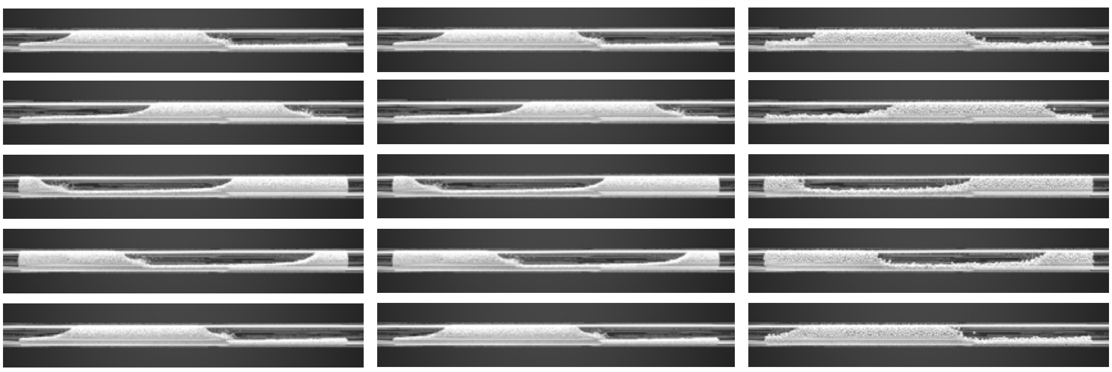
These results show that the coarse grain model can simulate the original particle system accurately.

REFERENCES

[1] Tsuji, Y., Kawaguchi, T., Tanaka, T., 1993, Powder Technology, 77, 79-87.

[2] Li, J., Webba, C., Pandiella, S.S., Campbel, G.M., Dyakowski, T., Cowell, A., McGlinchey, D., 2005, Chemical Engineering and Processing, 44, 167-173.

[3] Konrad, K. and Davidson, J.F., 1984, Powder Technology, 39, 191-198.



(a) Case 1: Original (b) Case 2: Coarse ratio 2.0 (c) Case 3: Coarse ratio 3.0

Fig. 1 Typical snapshots of the simulation results