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DISCRETE PARTICLE MODELING OF THE SOLID PHASE OF GAS-SOLID FLUIDIZED BED OF THE PNEUMATIC-VIBRATION SEPARATOR

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Gas-fluidized beds consist of granular particles that are subject to a gas flow from below, large enough so that the gas drag on the particles can outbalance gravity, and the particles fluidize. When in the fluidized state, the moving particles work effectively as a mixer, which results in a uniform temperature distribution and a high mass transfer rate, both of which are beneficial for the efficiency of many physical and chemical processes, such as coating, granulation, drying, and the synthesis of fuels and base chemicals [1]. Fluidized bed is also formed in pneumatic-vibration separator for coal treatment.

In order to enhance efficiency of the separator it requires a sound understanding of the process of separation which means a need for proper mathematical model. However, the prime difficulty in modeling life-size fluidized beds is the large separation of scales: The largest flow structures can be of the order of meters, yet these structures can be directly influenced by details of particle-particle collisions and particle-gas interactions, which take place below the millimeter scale. We can classify these different models most conveniently by considering the possible models for the solid phase and the gas phase separately. The dynamics of each of these phases can be described by (a) considering the phase as a collection of discrete particles that obey Newton’s law, which requires a Lagrangian (L) type of model, or (b) adopting a continuum description of the phase, which is then typically governed by a Navier-Stokes-type equation, which requires a Eulerian (E) type of model. Based on these two options for each phase, we categorize the different models available for gas-solid flow:

- Discrete bubble model. Gas phase – L, solid phase – E. Gas-solid coupling – drag closures for bubles. Scale – industrial (10 m)
- Two-fluid model. Gas phase – E, solid phase – E. Gas-solid coupling – gas-solid drag closures. Scale – engineering (1 m)
- Unresolved discrete particle model. Gas phase – E (unresolved), solid phase – L. Gas-solid coupling – gas-particle drag closures. Scale – laboratory (0.1 m)
- Resolved discrete particle model. Gas phase – E (resolved), solid phase – L. Gas-solid coupling – boundary condition at particle surface. Scale – laboratory (0.01 m)

– Molecular dynamics. Gas phase – L, solid phase – L. Gas-solid coupling – Elastic collisions at particle surface. Scale – mesoscopic (<0.001 m)

A graphical representation of the models is shown in Figure 1. Loth [3] has made a similar classification in a more general context for engineering science (including bubbles and droplets).

Only models 1–3 (the discrete bubble model, the two-fluid model, and the unresolved discrete particle model, respectively) are used for the simulation of actual gas-fluidized beds. Model 4 (the resolved discrete particle model) is used for small, representative parts of fluidized beds, whereas model 5 is only suitable for very small (colloidal) systems. The grid indicates the scale on which the continuum phase is solved.

To achieve proper accuracy model for pneumatic-vibrating separator must be of type of the model 3 or 4 (table 1). In both cases the solid phase of the gas-fluidized bed is modeled using discrete element method.

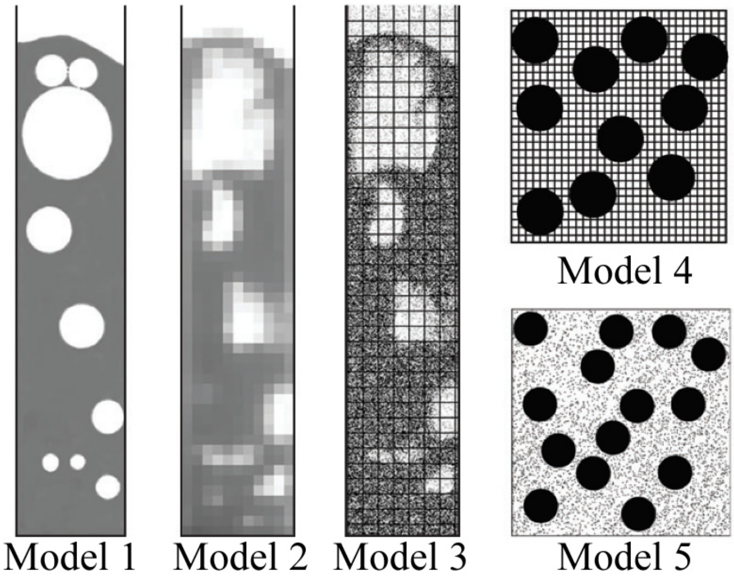

Figure 1 – Graphical representation of the models

In this paper we will define the particular model to use for our studies of granular material processed by pneumatic-vibration separator. The continuous increase in computing power is now enabling researchers to implement numerical methods that do not focus on the granular assembly as an entity, but rather deduce its global characteristics from observing the individual behavior of each grain [5]. Due to their highly discontinuous nature, one should expect that granular media require a discontinuous simulation method. Indeed, to date the Discrete Element Method (DEM) is the leading approach to those problems. Modeling is straightforward: the grains are the elements, they interact through local, pairwise contacts, yet are also subject to external factors such as gravitation or contacts with surrounding objects, and they otherwise obey Newton’s laws of motion. The DEM is a numerical approach where statistical measures of the global behavior of a phenomenon are computed from the individual motion and mutual interactions of a large population of elements. It is commonly used in situations where state–of–the–art theoretical knowledge has not yet provided complete understanding and mathematical equations to model the physical system.

Developing a DEM software often causes scientists to focus on marginal problems not related to their scientific work, such as: program interface, input/output of data, mesh generation or visualization of results. One solution is to use existing scientific frameworks, and plug–in one’s own calculation algorithms (Abaqus, Dyna, Adina, PFC3D etc). However these frameworks rarely give the possibility of combining together different modelling methods such as FEM, SPH, DEM or other custom simulations.

The solution proposed in [4] is to use a framework named YADE–OPEN DEM which will provide a stable base for scientists to operate on. Using an open–source development model will allow direct feedback from authors and encourage the scientific community's participation. By application of a proper software design the valuable work of others will be preserved and reused. The DEM chosen uses position, orientation, velocity and angular velocity as independent variables of simulated particles which are subject to explicit leapfrog time–integration scheme (Lagrangian method). The three–dimensional dynamics equations based on the classical Newtonian approach for the second law of motion are used. The track of forces and moments acting on each particle is kept at every time–step. Contact forces depend on the particle geometry overlap and material properties. The normal, tangential and moment components of interaction force are included.

An example model has been created that illustrates abilities of the chosen DEM framework (Figure 2). The model includes 240 spheres of equal size that are subject to gravitational force. On the Fig.2 we can see the spheres falling down.

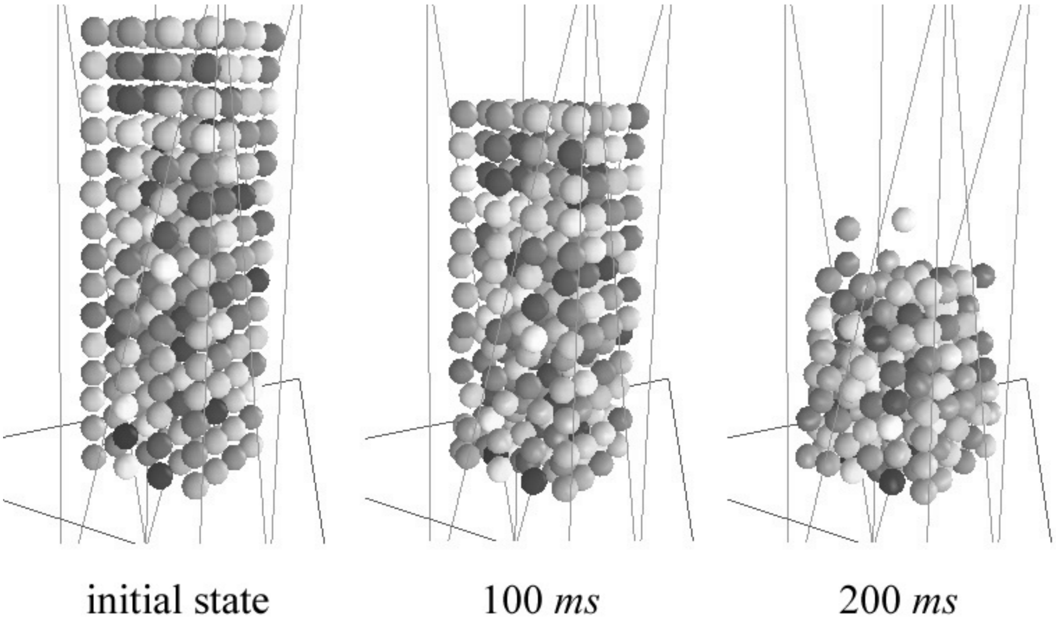

Figure 2 – A simple model of granular material

Further studies will be devoted to setting YADE particularly for pneumatic-vibration separator and creating a valid model.

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