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Sensitivity analysis of granular dynamics by the use of unique DEM

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Abstract: In this study we focus on particle imperfections and simplification of processes and phenomena to their direct and/or indirect influence on the dynamics of granular matter. This has significant meaning where one may use the Discrete Element Method (DEM) for large scale computations as well as for tiny particles, i.e. particles having ultrafine dimensions. Particularly, we assess how particle size distribution (PSD), frictional forms of particle-particle collisions and Van der Walls and liquid cohesive forces, shape the particle motions. We show how neglection of above features influence on computations of particle positions and particle linear and angular velocities over time.

Keywords: granular dynamics, DEM, fractional repulsive force, particle frictions, particle cohesions

1. Introduction

Discrete Element Method (DEM) [3] is one of most popular approach that model the dynamics of granular matter and/or granular flows. Every particle is distinguished as an individual object, where its motion and linear and angular velocities versus time are registered. In this approach particle-particle and particle-wall interactions play the dominant role and many simplifications given in the modelling process could not reflect the real dynamics of particle motions. This unproper dynamics is highly visible in particles having very low dimensions – called fine or ultrafine particles, and for high particle concentrations in space where multiparticle collisions occur. In this study we show how simplifications in the mathematical modelling have strong influence on the dynamics particle motions, i.e. drastic changes of particle trajectories and particle velocities.

2. Results and Discussion

We assume population of particles where *n* indicates the total number of particles which one takes into account in computer simulations. Individual motion of centre-mass of particle "*k*" is described by the following system of ordinary differential equations:

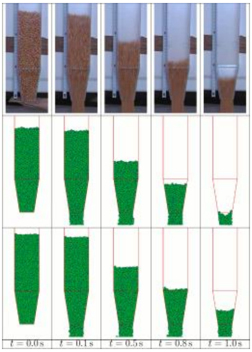
$$\begin{cases} m_{p_k}\ddot{\mathbf{x}}_{p_k} = \sum_l \mathbf{F}_{p_l} \\ \mathcal{I}_{p_k}\dot{\boldsymbol{\omega}}_{p_k} = \sum_l \mathbf{M}_{p_l} \end{cases} \tag{1}$$

for particles moving individually, i.e. without particle-particle or particle-wall collisions and

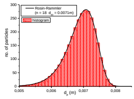
$$\begin{cases} m_{p_k}\ddot{\mathbf{x}}_{p_k} = \sum_{j(k),j(k)\neq k} \left(\mathbf{P}^{rep}_{j(k)} + \mathbf{P}^{att}_{j(k)}\right) + \sum_l \mathbf{F}_{p_l} \\ \mathcal{I}_{p_k}\dot{\boldsymbol{\omega}}_{p_k} = \sum_{j(k),j(k)\neq k} \left(\mathbf{M}^{rep}_{j(k)} + \mathbf{M}^{att}_{j(k)}\right) + \sum_l \mathbf{M}_{p_l} \end{cases} \tag{2}$$

taking into account particle-particle or/and particle-wall collisions. Symbolic meaning for above expressions one can find in [1,2].

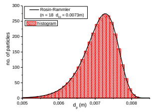
Let us show the first case, where variations of initial PSDs are taken into account. Fig. 1 shows the dynamics of emptying of a container filled by dry-pea particles.



Experimental data: 4000 dry pea particles
H_{bed}=26.8 cm
$T_{discharge}$=1.16 s ± 0.04 s
Initial PSDs: Rosin-Rammler distribution



n=18, d_{63}=0.0071 m



n=18, d_{63}=0.0073 m

Fig. 1. Initial PSD and its influence on the discharge dynamics of pea particles from a container

Note that small variations in d_{63} delays outflow of particles, i.e. prolongs the discharge time. Fig.2 shows another scenario, i.e. the particle positions for friction and frictionless particle collisions.

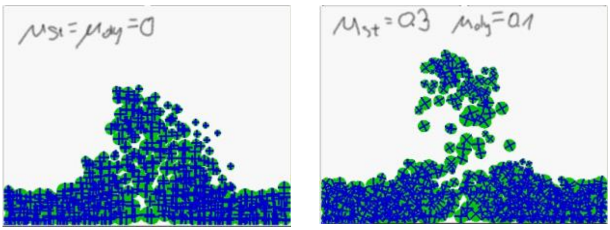


Fig. 2. The dynamics/screenshot of 500 ultrafine particles for t=1 s: left figure – friction-less particle collisions; right figure – static/dynamic particle frictions

Note that neglecting particle frictions one observes different particle motions.

3. Concluding Remarks

In this study we highlighted some particular aspects of DEM taking into account sensitivity analysis of variations in initial PSDs as well as friction/frictionless particle collisions having direct influence on the particle dynamics. Reflecting the real scenarios one should take into account preliminary assessment of processes and phenomena influencing to the dynamics of granular matter.

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