Penetrating process simulation of a ball in granular media

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Summary In this paper, the penetrating process is simulated with discrete element method (DEM). The penetrating depth of a ball with different initial velocities is studied. The simulate result is very similar to the QY Zhang's experiment result. it is proved that DEM is an idea method to study the mechanical behaviour of granular.

Model

In order to simplify the problem, moving object is assumed to be a ball and the shape of granular is assumed to be spherical. The model is composed of distinct particles that displace independent of one another and interact only at contacts or interfaces between particles. If the particles are assumed to be rigid, and the behaviour of powder of the contacts is characterized using a soft contact approach, in which a finite normal stiffness is taken to represent the measurable stiffness that exists at a contact, then the mechanical behaviour of such a system is described in terms of the movement of each particle and the inter-particle forces acting at each contact point. Newton's laws of motion provide the fundamental relationship between particle motion and the forces causing that motion [1,2].

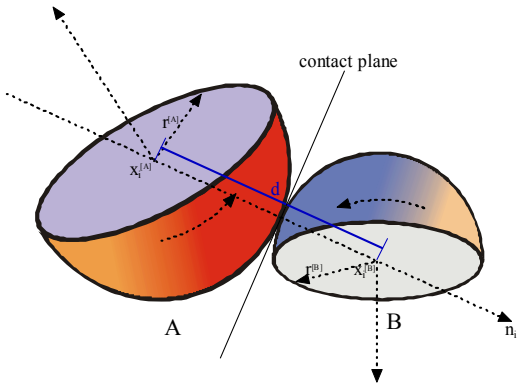

Fig.1. Contact condition between particles

Table 1 Simulation parameters of the filling density

Parameters of the simulation			
Parameter	Value	Parameter	Value
k_n	$1000\ N/m$	k_s	$1000\ N/m$
μ	0.3	γ_n	0.7
ρ	variable	g	$9.8\ m/s^2$
N_b	1	N_s	200000

For detecting particle-particle contact, the normal vector in radial direction, n_i, is defined.

$$n_i = \frac{x_i^{[B]} - x_i^{[A]}}{d} \tag{1}$$

Where d is the distance between two centre of the sphere:

$$d = \left| x_i^{[B]} - x_i^{[A]} \right| = \sqrt{\left(x_i^{[B]} - x_i^{[A]} \right)\left(x_i^{[B]} - x_i^{[A]} \right)} \tag{2}$$

Law of Motion is defined below:

$$a_i = F_i / m \tag{3}$$

$$v_i = v_i + a_i \Delta t \tag{4}$$

$$x_i = x_i + v_i \Delta t \tag{5}$$

Parameters

In the simulation, we choose the parameters as Tab.1 [3].

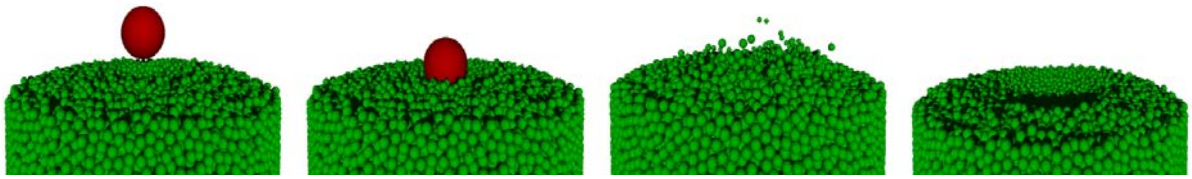

Fig.2. The side face view of penetrating depth

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Simulation of penetrating process

QY Zhang[4] does an experiment on penetrating depth, and there are about 800000000 granular with its radii 74 — 100μm in the granular media. In the simulation, 200000 sphere particles with the density 70 kg/m^3 are used to instead of 800000000 granular to save calculate time. The penetrating process of simulation is showed in the fellow figures.

QY Zhang had already get the experiment results on penetrate depth, the experiment results are showed in Fig.4 and Fig 6. Fig 4shows the relationship between penetrate and time. Fig 6 shows the relationship between ball's velocity and time. Fig 3and Fig 5 show the simulation result. Compared Fig 3 and Fig 4 , the simulation result is very similar to the experiment result.

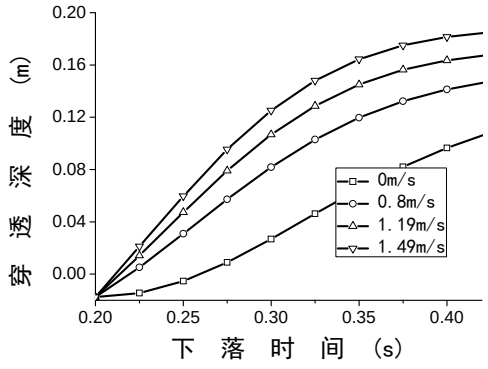

Fig.3 The relationship between sinking depth and time

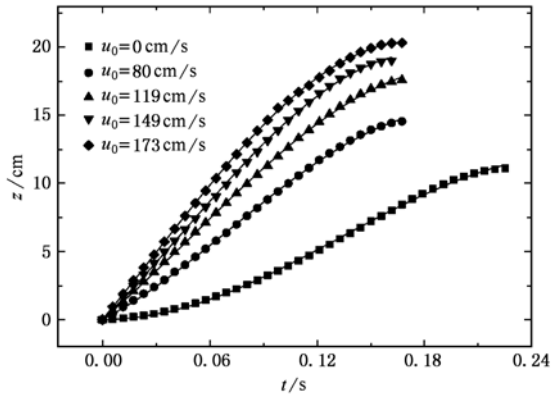

Fig.4 The relationship between sinking depth and time from experiment

Compared Fig 5 and Fig 6 , the simulation result is very similar to the experiment result too.

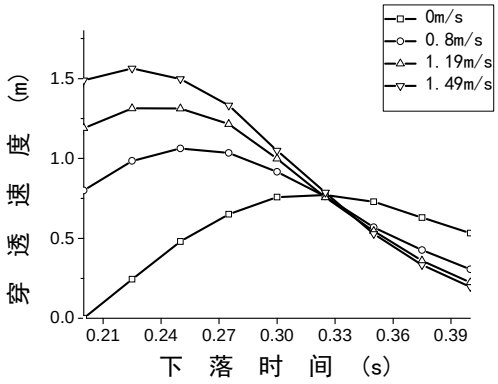

Fig.5 The relationship between speed of big ball and time

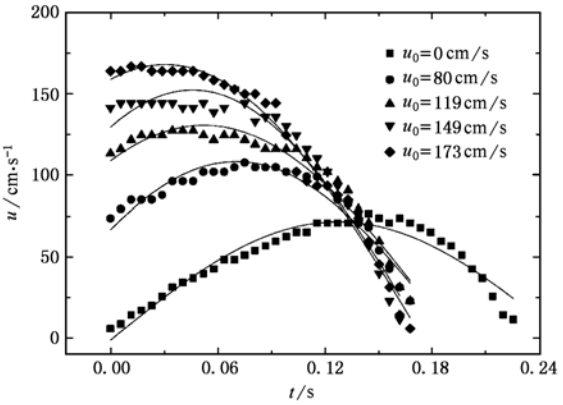

Fig.6 The relationship between speed of big ball and time from experiment

Conclusions

In this paper, the penetrating process is simulated. The simulate result is very similar to the QY Zhang's experiment result. It is proved that in the simulation the effect of enough sphere particles is the same as large granular in the experiment. But it is not sure how many particles is enough to instead of large granular. In fact, the shape of granular is not spherical. while in the simulation , we assumed the shape of particles is spherical , but the simulated penetrating process is very similar to the experiment. It is proved that the results are not sensitive to the shape of large number particles in DEM simulation.

References

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