Collision and diffusion in powder layer

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According to previous experimental results, a powder layer makes the coefficient of friction small on plywood track board. Coefficient of friction is 0.1-0.3 on powder layer and is about 0.35 on plywood. We hypothesize that it is because dynamic pressure of powder acts on the sole of rigid body and floats it, but it is not certified.

Why does rigid body decelerate slowly on powder layer? To answer this question, we simulated powder layer mainly with two model. The first model is 'two-dimentional DEM model' and the second model is 'Billiards model'.

Distinct element method (DEM) describes the motion of multitudinous, two-dimentional, disc-shaped particles.

Interparticle force in direction normal to tangent to contact point is modeled coupled spring and dashpot connected in parallel. Similar coupled spring and dashpot in series with frictional slider connects the particles in direction tangential. We can change property of particles by changing elastic coefficient of spring, viscosity coefficient of dashpot and friction coefficient of slider.

With this method, we modeled rigid body sliding on powder layer as follows. (1) Particles compose powder layer, track board and plate as rigid body. (2) Particles composing powder layer move freely. (3) Particles composing track board do not move. (4) Particles composing plate move together only x- and z-direction. Plate do not rotate. (5) Particles outside of left border appear inside of right border and vice versa. (6) Initially plate only moves.

We checked the change of the velocity of plate and obtained the coefficient of friction. We conducted 216 experiments (combinations of 27 series of parameters of particle's property and 8 series of plate's figure). In every case, coefficient of friction was about 0.3. Plate did not decelerate slowly as rigid body on powder layer.

Two-dimensional model does not seem to answer the question of low friction of rigid body on powder layer observed in three-dimetional experiments. What is the difference between two-dimension and three-dimension?

After a particle collide with other one, it mainly moves opposite in direction of which it moved before the collision in two-dimension, however, it moves randomly in three-dimension.

Then, we made a new model for comparison of dimensions based on this difference of rule of collision. With this model, diffusion and damping of kinetic energy both in two-dimension and three-dimension is examined firstly. In this experiments, particles are arranged in equal distance inside a rectangle, only one particle moves initially (Billiards model)

As the result, when coefficient of restitution of particle is 1.0, larger diffusion of kinetic energy was observed in the two-dimensional model comparing with three-dimensional model. When coefficient of restitution of particle is less than 1.0, damping of kinetic energy of two-dimension is faster than that of three-dimension.

A ratio of the weight of the body and frictional force determines a coefficient of friction of rigid body. Powder layer sustains a rigid body, but it also resists a moving body. If particle have some momentum, the maximum impulse of frictional force is fixed, and collision of particles with body emerge the force sustaining the body's weight. It means that it is the frequency of collision of particle with rigid body that defines a coefficient of friction of body. Slow damping of kinetic energy causes many collisions of particles with rigid body and many collisions cause low coefficient of friction.

Kinetic energy damps slower in three-dimension than in two-dimension. Three-dimensional model can lessen the coefficient of friction of rigid body on powder layer.