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# SIMULATION OF POWDER BEHAVIOR BASED ON DISCRETE MODEL TAKING ACCOUNT OF SURFACE EFFECT OF PARTICLES

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**Summary.** *An attempt is made to a new compaction model, which may agree well with experimental result when the particles are very adhesive. Adhesion force and resistance force by liquid bridge between particles are incorporated and simulation is carried out. A simulation of two particles' collision is first carried out, and then a simulation of free fall of many particles is carried out. When two particles collide with one another, they stick together. And when many particles fall by the gravity, they form clusters and the density of assembly of the particles is low because there are large or small cavities among the clusters. Thus, in these simulations, the effect of adhesion of particles is seen very clearly.*

## 1 INTRODUCTION

In the past, simulations of compaction have been carried out based on a particle model, considering repulsion by Hertz's force and attraction expressed by a dash-pot model. But the dash-pot model has no physical background. As far as metal powder is concerned, they agree well with experimental results. In case of ceramics powder, however, especially in the case of fine powder, they don't agree with experimental results. As the particles becomes smaller, interaction between particles, such as attraction caused by the moisture of the particle surface, van der Waals force, electric static force, and so on, gives more influence to the behavior of the powder. Therefore we should take account of attraction between the particles in detail. In this research, we suggest a particle model considering attraction between the particles and carried out the simulation of powder behavior.

## 2 SIMULATION MODEL

First, we carried out 2-D simulation of collision of two particles, which diameter was 2.0[$\mu$m]. We arranged two particles with their centers 2.05[$\mu$m], i.e. a gap of 0.05[$\mu$m] between them, and gave initial velocities of 0.01[m/s].

Second, we arranged a hundred particles at random in the 25[$\mu$m] $\times$100[$\mu$m] cell, and gave them initial velocities with random directions and magnitudes.

In the calculation, we consider following four forces;

1) Adhesion force by liquid bridge between particles[1, 2]

A couple of molecules of water cover the surface of particles. When particles come close to each other, liquid bridge is formed up by the molecules. Because of the surface tension of the liquid bridge, adhesion force is generated at the surfaces of the particles. The strength of this force depends on the various parameters such as percentage humidity, diameter of particles and so on. As the distance of particles' surface gets closer, this force becomes stronger. And if the particles approach within a small distance, this force becomes rapidly large.

2) Resistance force by viscosity

When particles come close to below a certain distance, the viscosity force is exerted because of the layer of moisture which covers the surface of the particles, and the relative velocity between the particles becomes small rapidly. We assume that the viscosity force applied between particles is proportional to the velocity of particles, when particles come close to below a certain distance.

3) Repulsive force

When particles get into touch with each other, repulsion force is exerted between the particles. We consider the repulsion force is assumed to be Herzian.

4) Gravity force

We consider the gravity force in the simulation.

The material and geometrical properties are listed in Table1.

| | |
|---|---|
| Particle diameter | 2.0 $[\mu m]$ |
| Young modulus | 350 $[GPa]$ |
| Poisson's Ratio | 0.24 |
| True density | 3.98 $[g/cm^3]$ |
| Time step | $1.0\times10^{-12}$ $[s]$ |

Table 1 : Material and geometrical data for simulation

## 3 RESULTS AND DISCUSSION

### 3.1 The collision of two particles

As time pass, the change in the gap between the two particles is shown in Fig.1, and the change in the adhesion force by liquid bridge, resistance force by viscosity and repulsion force are shown in Fig.2. While particles are sufficiently far away from one another, their velocities are constant. And if the one particle comes close to the other particle, the resistance force rises by their viscosity and thus their velocities decrease. Then particles come much closer to one another, they attract each other strongly by the adhesion force by liquid bridge. They stick together where the repulsion force balanced out the adhesion force and oscillated with a very small amplitude. The relationship between the gap between the two particles and the adhesion force by liquid bridge are shown in Fig.3. The adhered particles do not separate from each other because strong liquid bridge force is applied to them.

### 3.2 Free fall of many particles

The snapshots of particles' behaviors are shown in Fig.4. First, a couple of particles stick together, because of the adhesion force between them, and form small clusters. Some particles near the wall are observed to stick to the wall. Then, some clusters contact others and form bigger clusters. Some of them stick to the wall, while others fall to the bottom of the cell by the gravity. Finally, all the clusters come to rest on the side wall or on the bottom. We see large or small cavities among the clusters and, therefore, the density of assembly of the particles is obviously small or smaller than in the case without adhesion force.

## 4 CONCLUSIONS

We carried out a simulation of collision of two particles and free fall of particles, considering the adhesion force and resistance force by liquid bridge.

When two particles collide with one another, first, their velocities obviously decrease because of the resistance force by their viscosity, and then, they stick together because of the adhesion force by liquid bridge between them.

When many particles fall by the gravity, first, a couple of particles stick together and form small clusters. Then some clusters contact others and form bigger clusters. Some of them stick to the wall or the bottom of the cell. The density of assembly of the particles is low because there are large or small cavities among the clusters.

In conclusion, we can simulate the adhesive particles' behavior by incorporating the liquid bridge between the particles. We consider that this model would be used in the simulation of compaction process of well adhesive particles.

## REFERENCES

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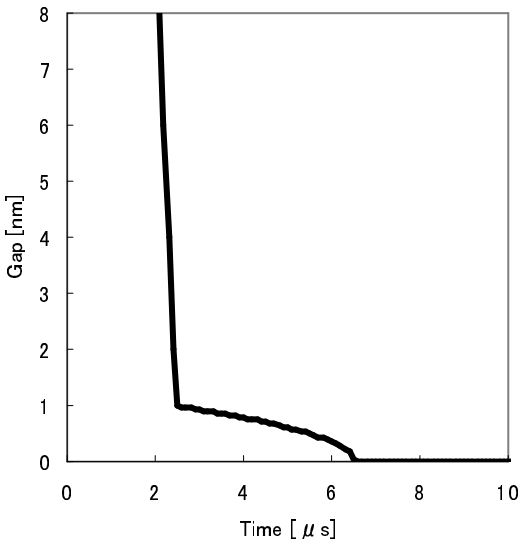


Fig.1: Gap between particles

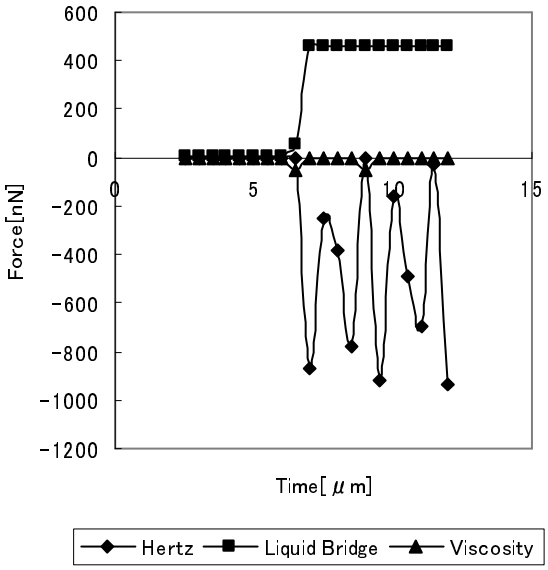


Fig.2: Strength of force

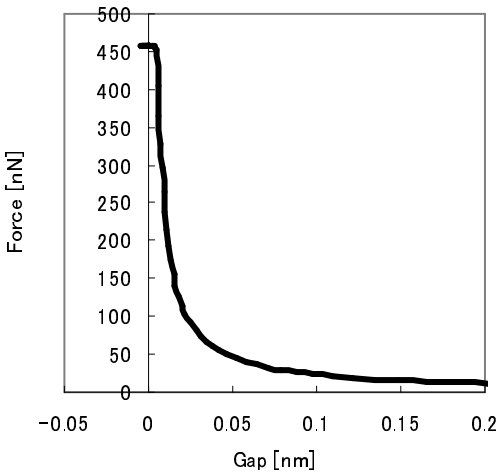


Fig.3 :Relationship between adhesion force and gap

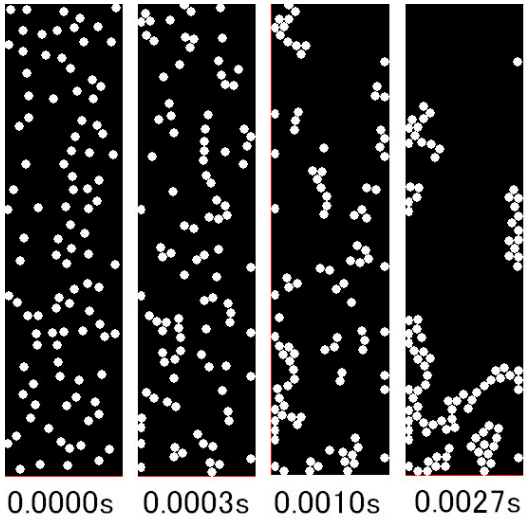


Fig.4: Snapshots of particles' behavior