DEM Simulation of a Screw Feeder Using the Adhesion Powder

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Abstract

The simulation of the screw feeder was carried out by a disintegration element method (DEM). This simulation model was compared with the feed rate of the small screw feeder at 45 mm diameter and 215 mm length with potato starch powder of 45 μm average particle size. The potato starch could change the adhesion force between the particles by controlling quantity of water. Therefore, it was used as adhesion powder. Each parameters of the DEM simulation determine the value of the angle of repose by comparing actual measurement value with simulation. In addition, the angle of repose was measured using potato starch containing the different moisture. As a result, the repose angle of the powder and the porosity increased by increasing quantity of moisture, and the flowability of the powder got worse. In the screw feeder of the actual machine, it was found that powder is hardly fed at 25% of moisture. Because a value of the adhesion was chosen properly, in simulation, we were able to reproduce flowability and feed rate of the powder well.

Keywords: DEM simulation, Screw feeder, Angle of repose, Moisture, Feed rate, Flowability

Introduction

Unit operation such as feeding and handling is always necessary in the process to treat powder. Screw feeder is shown as the device which can convey powder in the constant flow and the constant speed(Hayashi, 1998). The design of this device is difficult because such feeder depends on particle size, size distribution and flowability greatly. If the particle size becomes small, powder adhesive power increases, and feeding accuracy will decrease. A powder kinetic property can be measured by the angle of repose and the bulk density. However, it is difficult to measure a powder bulk density in the feeder(Kimata,et.al. 2001). Furthermore, it seems that the feed rate of the powder is affected by the screw shape of the feeder and the roughness of the cylinder surface. It is hard to make the devices for every experiment condition. In the feed process of powders, the trouble such as blocks by the adhesion of powders is easy to happen, and it is necessary to predict the behavior(Sakashita, 1998).

On the other hand, for speedup of the computer processing, computer simulation about the powder flow is carried out widely. And the understanding of the phenomena in various powder processes is progressing. Discrete element method (DEM) is used as simulation to handle the powder flow well(SPTJ, 1998 and Hidaka, Katsura 2003). This dissolves a motion equation of individual particles discretely, and kinetic properties of the particle bed are explained, because the interaction of those particles is calculated. Therefore, in this study, we handled the adhesion change of powders "it is one of the causes of the block in the screw feeder" as its moisture change. About the kinetic property of those powders and a change of the feed speed with the actual machine, it was aimed at analyzing it by DEM simulation using numerical analysis software "RFLOW". The parameter to show the interaction between particles in the DEM simulation cannot just use the value to be different from a physical properties value of the real particle. Therefore it is necessary to make a physical properties value and the particle parameter of powders provide when we carry out DEM simulation. And we compared an actual value and the simulation value in the cheap angle of repose which was a representative physical properties value of powders. Then, the dynamic property of moisture controlled powders was measured, and relations between the powder moisture and the adhesion force were investigated. Furthermore, influence of the powders moisture was investigated by carrying out the DEM simulation that adhesion force was given between particles.

Experimental

Sample Powder

Potato starch (Hokkaido, Japan product, an average particle diameter: 45.4 μm) was used. The moisture of the powder was controlled by 3.6 - 25.4 % by using a sprayer and a drying machine kept at 60 degrees Celsius.

Dynamic Measurement of Powders

Powder tester PE-T (Hosokawa Micron Corp.) was used for the measurement of the repose angle, and that porosity and the bulk density of the sample powders controlled for water. The tensile test and the shear test were conducted by a powder bed tester (Sankyo Piotech Co., Ltd.). A Mohrs circle was drawn by a obtained result, and flow index *FI* [m] was calculated.

$$\mathrm{FI} = f_c / (\rho_b \cdot g) \tag{1}$$

Where, f_c is uniaxial collapse stress, ρ_b is bulk density of the powder and g is acceleration of gravity.

Feed Experiment

Two screw feeders (Akatake engineering Co., Ltd.) of an inside diameter: 45 mm, a screw diameter: 35 mm, a shaft diameter: 18 mm, pitch: 28 - 32 mm, the distance from hopper to an outlet: 215 mm (short type) and 1155 mm (long type) were used. After sample powders were put in Hopper, with screw number of revolutions set in 0.4 - 0.82 rps, a measurement of the powders mass from an outlet was started with a turn by a road cell. The feed speed was calculated from the mean of a feed provided every five seconds.

DEM Simulation

Typical analysis conditions were shown in **Table 1**. And the short screw feeder model was shown in **Figure 1**. Using the screw feeder model of dimensions same as an actual machine, the analysis that changed adhesion from 10^{-8} N to $5\mathrm{x}10^{-6}$ N was carried out. The analysis results were compared with the actual values, respectively.

Table 1. Simulation conditions of the short screw feeder

RPM scale ratio [-]	33
Density [kg/m^3]	1521
Num. of particle [-]	90040
Adhesion force [x10^{-6} N]	0, 0.01 - 5
Spring const. [N/m]	7000
Restitution coef. [-]	0.1
Friction coef. (Particle-Particle) [-]	0.36
Friction coef. (Particle-Wall) [-]	0.7
Rotational speed [rps]	0.8

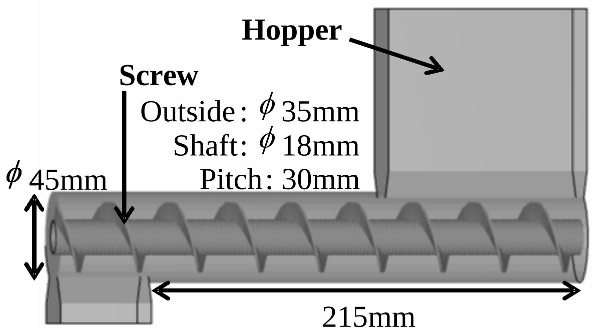

Figure 1. Schematic diagram of short screw feeder

Results and Discussion

An angle of repose of potato starch controlled to 3.6 - 21.0 % of moisture was shown in **Figure 2**. And the porosity when an angle of repose was measured was shown in addition. The red plot shows an angle of repose, and the blue plot shows porosity. In this figure, it was found that the angle of repose and the porosity increased with increase of the moisture. In the case of 10-15% of moisture, the angle of repose was increased greatly. Therefore, it is thought that flowability of the sample powder rapidly gets worse at this time.

In two screw feeders which the sample powder of 5.5 - 25.4 % of moisture was used for, the relations between supply speed *X* and number of revolutions *N* were shown in **Figure 3**. In this figure, straight line relations were provided between supply speed and number of revolutions with all moisture. And these relations were arranged in the next equation.

$$X = \alpha \cdot N \tag{2}$$

Where, α is experimental constant about the feed speed. In addition, the feed speed decreased with increase of the moisture. Furthermore, it was stopped up in the trough inside when we exceeded 25.4% of moisture. And the phenomenon that it could hardly feed was confirmed.

A powder yield locus and a Mohrs circle were drawn on powder of the different moisture by the measurement of the powder bed tester. From those results, calculated flow index *FI* and the feed rate constant α by the feed experiment of the actual machine were shown in Figure 4. In this figure, it was found that the rate constant α decreased with increase of *FI* namely flowability got worse. Therefore, it was confirmed that a good correlation was provided between the dynamic property and feed rate of the powders having different moisture.

Angles of repose by the real potato starch with different moisture and by the DEM simulation in consideration of adhesion force were shown in Figure 5. A red plot shows an actual value by the potato starch, and a blue plot shows a simulation value. In this figure, there is unevenness in those values. However, a tendency to increase greatly was seen in the angle of repose (35 - 67 degree) of the actual value by the potato starch with the increase of the adhesion force (0 - 10^{-6} N). Therefore, it was found that the flowability of model particles got worse by considering an adhesion force. The possibility that could reproduce adhesive powders by setting an appropriate adhesion force was suggested.

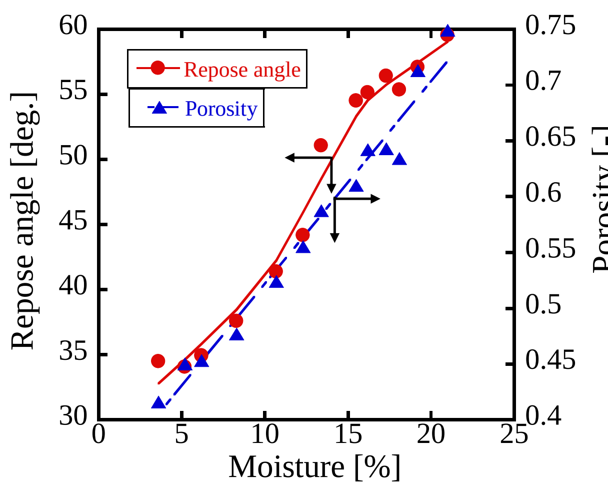

Figure 2. Repose angle and porosity as a function of sample moisture

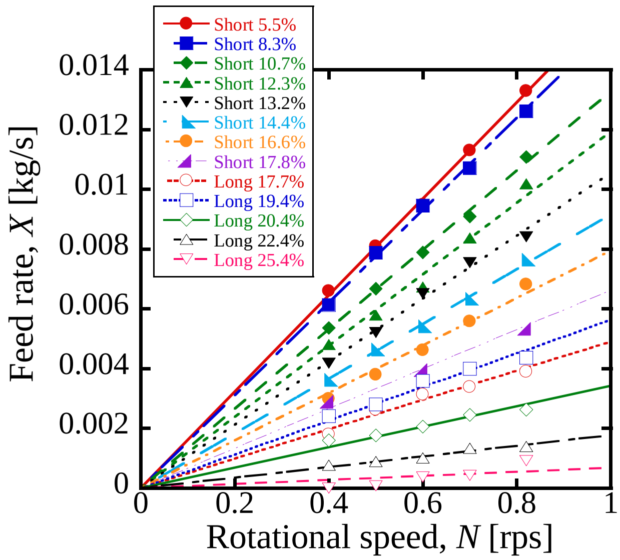

Figure 3. Relationships between *X* and *N*

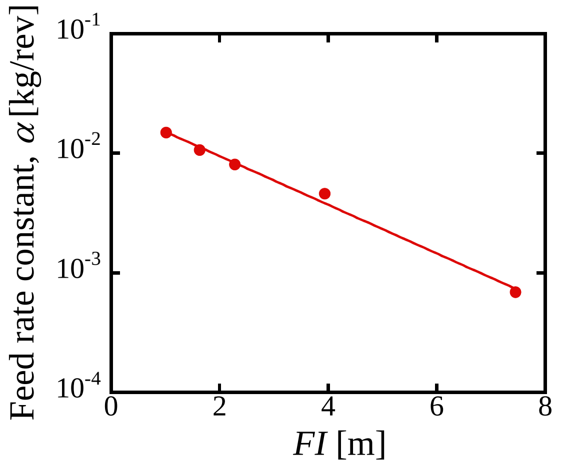

Figure 4. Relationship between *α* and *FI*

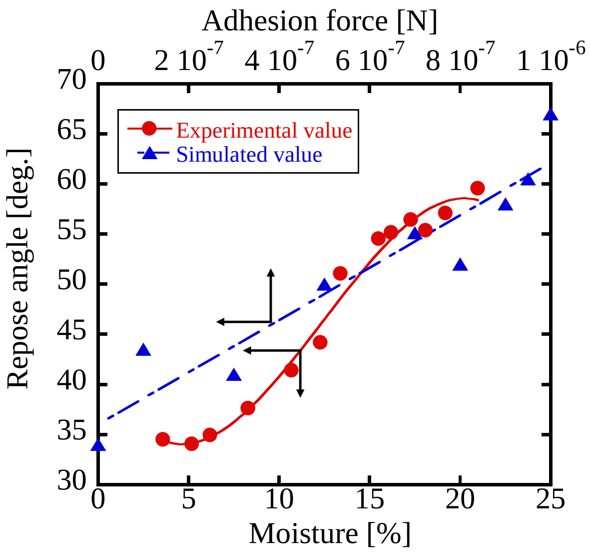

Figure 5. Repose Angle as a function of moisture and adhesion force

The values of feed rate constant *α* by the screw feeder with the actual machine by the DEM simulation that adhesion was considered were shown in Figure 6. In this figure, feed rate tested with an actual machine with increase of the moisture decreased. As a similar tendency, the feed rate decreased by the simulation by giving adhesion. In addition, it was found that the feed rate of the model powders to approximately 8% of moisture could reproduce in the range of an adhesion force set by this simulation.

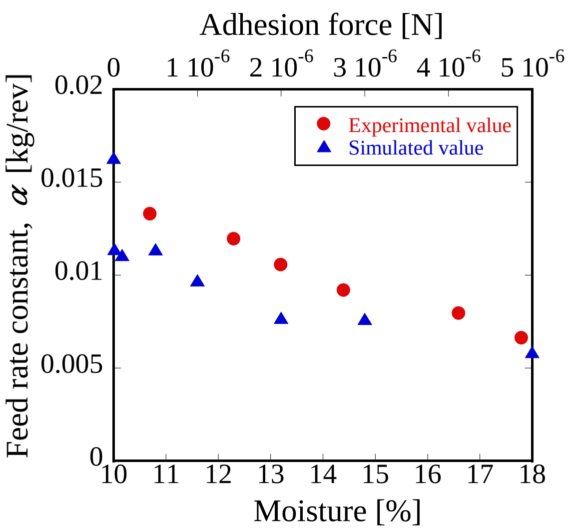

Figure 6. Feed rate constant *α* as a function of the moisture and the adhesion force

Conclusions

It was found that feed rate changed by a difference of the moisture. In addition, in the comparison between the dynamic property and supply rate of the powder in moisture different, it was confirmed that they were satisfactory correlations. It understood that we could control behavior and the feed rate of the particles by an appropriate adhesion force being considered. From these results, the possibility that could reproduce the occlude behavior in the screw feeder was suggested.

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