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DEM Simulation on the Mixing of Rice Husk Powder in a Screw Feeder with Various Screws

Mitsumasa Kimata*, Yuzuru Endo, Kenta Banzai, and Masahiro Hasegawa

Department of Chemistry and Chemical Engineering, Yamagata University
4-3-16 Jonan, Yonezawa, 992-8510, Japan. kimata@yz.yamagata-u.ac.jp

The screw feeder is used as an expensive feed device of the precision widely industrially. This device can expect further use expansion if we can add mixed ability to this. However, the screw shape affects the experiment about the powder mixture. The experiment with many screws of the different shape and the observation of the internal particle will be very difficult. Therefore, in this study, we simulated the screw feeder by using a discrete element method (DEM) of numerical analysis software "RFLOW". The parameter of the DEM simulation was decided by comparing the angle of repose of the powder. The simulation using seven kinds of screws was carried out, and mix property was evaluated. When we used single screw, it was found that a result of the simulation corresponded with a real experiment result well. It was found that a cut screw was high in the most mixed ability, and a ribbon screw was low in the most mixed ability as a result of simulation with various kinds of screws.

1. Introduction

Unit processes, such as feeder and conveying, are indispensable to almost all the handling processes a powder and granular material. A feeder is generally installed before and after many fine particles processing units, grinding, storage, granulation, measurement equipment and others. Feeder performance of high accuracy is demanded for various kinds of powder by the complexity of the powder processes. The screw feeder is one of the equipment, which can feed a powder with high accuracy (Hayashi, 1998). We can contribute to the labor saving of the process if we can add mixed performance to such a screw feeder as well as a role of the supply and can expect the expansion of the use. It seems that the screw shape of the feeder and the roughness of the cylinder surface affect the feed rate and mixture of the powder. Therefore, necessity to remake equipment every condition occurs by the experiment, and trouble and economic burdens increase. In addition, it is necessary to observe a motion of particle situation in the feeder in detail. However, it is difficult to observe it in the experiment with the actual machine from the exterior.

In recent years, computer simulation about fine powder flow came to be actively performed by the speedup of the computer process of the computer. Thereby, an understanding of many phenomena in various powder and granular material processes are progressing. As a simulation model treating a powder flow, the discrete element method (DEM) proposed by Cundall and Strack (1979) has reported. DEM solves the equation of motion of each particle discretely, and although it is approximation, it

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calculates directly in consideration of the multi body interaction of particles, it can simulate the kinetic property of a particle layer with sufficient accuracy (Manickam et al., 2010; Mio et al., 2009). However, the parameter to show the behavior of the particles by DEM simulation cannot use a physical properties value directly to be different from a physical properties value of the real particles. Therefore, when performing a DEM simulation, it is necessary to match the physical properties value of actual particles and the particle parameters used on a simulation. In this study, DEM simulation was carried out using numerical analysis software RFLOW (Rflow Co., Ltd.). The powder parameters were determined the measurement of repose angle and convey experiment of the screw feeder by a comparison with the simulations. Subsequently, various kinds of screw models were made based on an actual feeder, and the mixed property of the feeder internal particle which a screw shape gave it to was evaluated by observing a tracer particle produced on simulation.

2. Experimental

2.1 Powders

A ground product of the rice husk (Rice husk powder, RHP, average particle size = 150 μm) which was pulverized by Bantam Mill (AP-B, Hosokawa Micron Co.) was used for measurement of repose angle and feeding experiments with single screw feeder mainly. Spherical ion-exchange resin (IER, average particle size = 637μm) was used for the powder mixed experiments with a screw feeder. The powder density was measured by the picnometer method, and RHP and IER were determined with 1,690 and 1,230 kg/m^3, respectively. As for the particles, an average particle diameter of RHP was used for the model particle in the simulation, because it was expressed with a uniform sphere in DEM simulation.

DEM has very large calculation load of a computer. A few numbers of particles in calculation cannot be handled to number of particles treated in actual industry because number of particles use for a simulation has limit. Therefore, it is difficult to apply a DEM to actual fine particles process directly. In that case the technique calculated using bigger particles than original particles, i.e., a representative particle model (RPM) may be taken because the action of all the particles in a system is reproduced with the limited number of particles (Kuwagi et al., 2002; Sakai and Koshizuka, 2009). By this RPM, even if it uses larger particles than original particles in a simulation, the transfer characteristic of particle movement can be simulated with sufficient accuracy.

"Bulk" of the fine particles produced by particle shape etc. namely the filling factor should consider as important element in order to improve the accuracy of a simulation. About non-spherical form particles, in almost all cases, filling factor becomes below the filling factor of spherical form particles. Therefore, as a technique of controlling the filling factor of the particles which are the dominant parameters of critical evaluation how to make pseudo-bulk was used by making the contact decision particle diameter larger than RPM particles (Sakai et al. 2003).

The software RFLOW was equipped with these functions, and contact decision particle was set up when the particle-filling factor of fine particles model was low by non-spherical form particles such as RHP.

2.2 Angle of repose

The physical properties value of real particles cannot be directly used for a DEM simulation. Therefore, when we carry out DEM simulation, it is necessary to determine the particle parameters used by DEM with the physical properties of the real particles. A method with the angle of repose, which is a typical macro phenomenon of powder, is often used. The particle parameters of the friction coefficient between particle-particles and particle-walls were determined by the comparison the gradient angle of repose between actual value and simulation value.

Figures 1 and 2 were shown typical experimental and simulation results of dynamic angle of repose. The experiment rotated a cylinder container of 80mm in diameter at 10mm in length and took a picture. The simulation made by RFLOW the container of the shape same as a real experiment, and it was calculated. In real experiment, as shown in Figure 1, angle of repose can be measured by two kinds of methods. *Figure 1*(a) is defined as the angle between linear to make an area of the undulation equal at the same time to go along the center of incline and level surface. On the other hand, *Figure 1*(b) is defined as the angle between stable part of incline and level surface. In this simulation, the angle of repose was measured by the same method as (b) of real experiment because almost all surges were not produced. We compared the simulation with the experiment by a trial-and-error method.

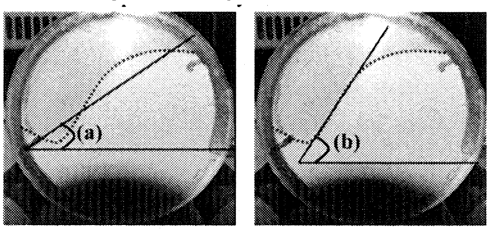

Figure 1: Experimental image of dynamic repose angle

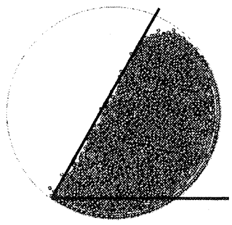

Figure 2: Simulation image of dynamic repose angle

2.3 Screw feeder

DEM model of the screw feeder was made by RFLOW, and powder conveying and mixing were simulated. The shape of the model and the real screw feeder were shown in Figure 3. We used the small screw feeder (Akatake Engineering Co., Ltd.) for the model at about 45 mm diameter and about 215 mm length. In the experiment, dried RHP was added to hopper and rotated a screw in 0.4 - 0.8 rps, and feed mass was measured in a road cell every one second. There is almost the same model with the screw feeder, which we used by the experiments. At first the particles were made in a hopper and a trough at random, and they were filled up by gravity. And, a screw was turned, and powder was feeder. We investigated the influence of the representative particle size, which gave it to feed rate mainly.

Next, we carried out the mixed analysis of the internal particle using two kinds of particles. Investigation of the mixed characteristics of the inside particles of a feeder created seven kinds of different screw form, and was performed by generating two kinds of particles inside a feeder about each model. Figure 4 shows various screw model actually created. Names of each screw forms are "single screw" about a simplest shaped screw, "cut screw" put the cut into the screw flight, "paddle screw" inserted the paddle at irregular interval the shaft of single screw, "cut paddle screw" combined the cut screw and the paddle screw, "reverse screw" inserted the turned screw only one pitch into the single screw, "ribbon spiral" made the shaft of the single screw thin, and "ribbon spiral without a shaft" removed the shaft of the single screw. In this place, the size of the feeder changed the length from a hopper back end part to an outlet into 455 mm from 215 mm on the basis of what was shown in Fig. 3. The reason is because it aims at observing in detail the effect of the particle mixture by screw form by increasing time for particles to touch a screw by lengthening the length of this portion. Two kinds of model fine particles used in this experiment were set to RHP and IER with a small density difference. The scale factor of representative particle diameter was set for ten times.

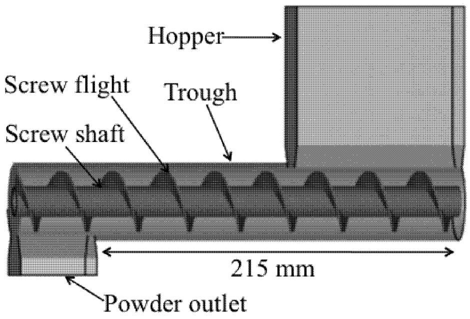

Figure 3: Schematic diagram of single screw feeder

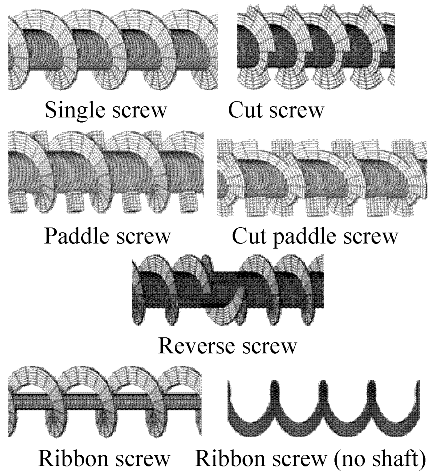

Figure 4: Various screw forms

3. Results and Discussion

3.1 DEM parameter and simulation of feed rate

Figure 5 was shown relationships between simulation result of repose angle and the friction coefficient of particle-particles. The experimental results of dynamic angle of repose measured by the method as shown in Figure 1 were indicated at the dashed lines in Figure 5. The Figure showed that the friction coefficient obtained from the intersection of an experimental value and a simulation value was 0.11 at the time of (a) and 0.36 at the time of (b). In addition, the friction coefficients between particle and wall were 0.68 and 0.54 about (a) and (b).

Figure 6 was shown in relationships between feed rate X and screw rotational speed N at various RPM scale ratios with an actual value when we used RHP. In this screw feeder, proportion relations were seen in between X and N. Furthermore, the relations of both obtained from this simulation did not depend on a scale of the representative particle diameter, and linear relations were provided between X and N and were able to arrange it in X = αN. Where, α is an experimental constant.

When representative particle diameter calculated at 8 to 12 times, agreement with these values were mainly shown without depending on a scale factor, but when it was as above 13 times, the simulation results were separated greatly. In this simulation when making the model of a screw feeder, the mesh diameter of the model was 2mm. Therefore, representative particle diameter considers equivalent and over the mesh diameter in cases where, it was thought that it is for the calculative error to have occurred. Moreover, the simulation value that was slightly lower than experimental value was shown at the time of 8 to 12 times representative particle diameter. It is considered that the phenomenon that compaction increases with the actual feeder to the conveyance direction was produced whereas the particle density by the scale factor of a contact decision particle diameter used by this simulation is constant.

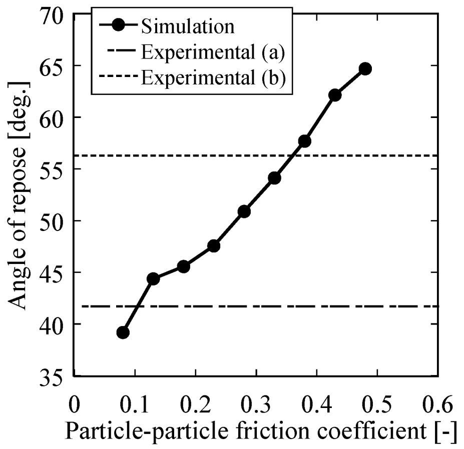

Figure 5: Relation between angle of repose and friction coefficient

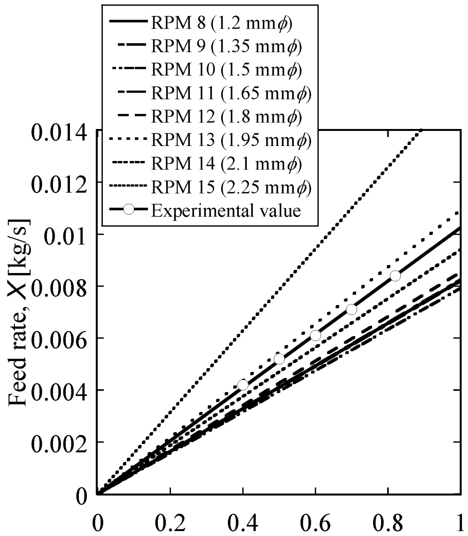

Figure 6: Relation between N and X

3.2 Evaluation of mixed feeder simulation using two kinds of particles

The generation situation of two kinds of particles just before the analysis start was shown in Figure 7. A is RHP, and B is IER and is shown with white and gray, respectively. The particles of two pitches behind from the hopper front edge were changed to IER after RHP was generated.

When various forms of the screw were used, relation mass fraction of fed IER from the screw feeder outlet and the feed time were shown in Figure 8. It is thought that it is in a shallow curve as for the temporal change of the mass fraction if mixture is carried out in the feeder inside. Therefore, "ribbon screw" and "ribbon screw without shaft" are unsuitable for mixture from the figure, and it proved that “cut screw” could expect mixture most. This is considered that the mixture in flight back was promoted by cutting a screw flight. As compared with a universal single screw, it proves that supply time of onset is overdue for a while except for two kinds of ribbon screws. This is considered to fall of the feed rate that the existence of the paddle of a paddle screw, cutting a screw flight and insertion the turned screw only one pitch into the single screw are the causes.

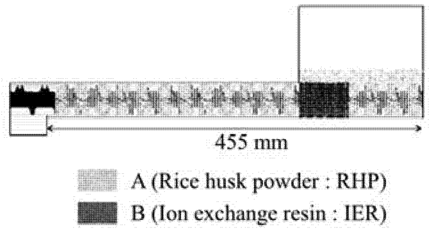

Figure 7: Schematic diagram of screw feeder of mixing simulations

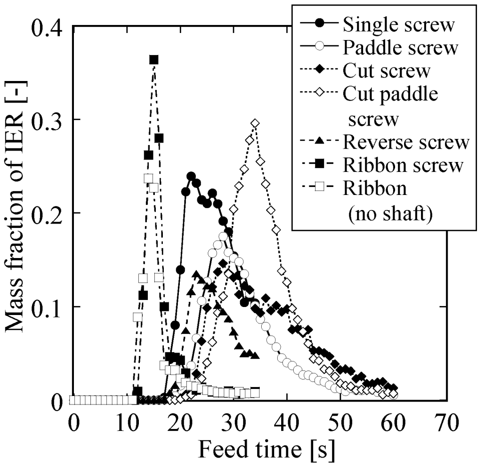

Figure 8: IER mass fraction as a function of feed time

4. Conclusions

When the dynamic angle of repose was used, the parameter of DEM simulation, which is mostly in agreement with an actual measurement, was matched. Representative particle diameter was mostly in agreement on the simulation about the feed rate results of the powder up to 8 to 12 times. It was found that the screw form of having been most suitable for mixture is a cut screw. Moreover, feed start time of mixed powders at feeder outlet became late except two kinds of ribbon screws.

References

Cundall, P.A. and Strack O.D.L., 1979, A Discrete Numerical Model for Granular Assembles, Geotechnique, 29, 47-65.

Hayashi, T., 1998, Powder Technology Pocket Book, Kogyo Chosakai, 282-288 (in Japanese).

Kuwagi, K., Takeda H. and Horio M., 2002, Giga-scale DEM Simulation by a Novel Similar Particle Assembly Model, JSME Annual Meeting, 309-310 (in Japanese).

Manickam, S.S., Shah R., Tomei J. and Bergman T.L., 2010, Investigating mixing in a multi-dimensional rotary mixer, Powder Technology, 201, 83-92.

Mio, H., Higuchi R., Ishimaru W., Shimosaka A., Y. Shirakawa and Hidaka J., 2009, Effect of paddle rotational speed on particle mixing behavior in electrophotographic system by using parallel discrete element method, Advanced Powder Technology, 20, 406-415.

Sakai, M. and Koshizuka S., 2009, Large-scale discrete element modelling in pneumatic conveying, Chemical Engineering Science, 64, 533-539.

Sakai, M., Yamamoto T., Murazaki M. and Miyoshi Y., 2003, Application of Distinct Element Method to Criticality Evaluation of MOX Fuel Fabrication Facility, The 7th International Conference on Nuclear Criticality Safety 2003, 460-465.