Granuleworks™
Advanced Simulator for Granular Materials

users interview

AICHI ELECTRIC CO., LTD.

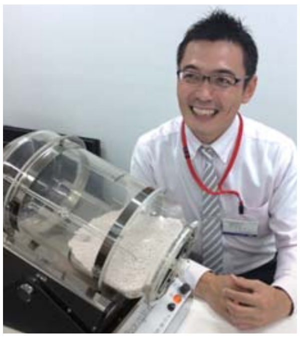
Powder mixing simulation for “Rocking Mixer”, container-rocking/rotating dry powder mixer

Aichi Electric Co., Ltd. was founded in 1942, Nagoya City, Aichi Prefecture, and has since grown in two fields: Electric power equipment business handling transformers, control equipment and power distribution automation systems, etc., for power companies, and the rotating machine business handling electric actuators based on motor technology, driving control devices, shutter opening/closing devices, and powder mixing machines. We interviewed Mr. Tadayuki Kurita of the Sales Group,Electric & Electronics Products Division at Aichi Electric Co., Ltd. about powder mixing simulations of the “Rocking Mixer”, container-rocking/rotating dry powder mixer.

Fig. 1 “Rocking Mixer” rocking/rotating dry powder mixer

Please tell us about your departments work

The Electric & Electronics Products Division is in charge of the motor, motor applied products and powder processing machine business. The R&D department, which I worked for until last year, has been mainly conducting research and developing new products such as DC motors for nursing care, housing and FA fields, electric actuators, driving devices, fans, and so on. Since I was in charge of research into the powder mixing field, I carried out powder simulation with the cooperation of Prometech. I am now working at the Sales Department of powder equipments and powder systems such as mixers, dryers, and transport machines. If you have any needs and problems of powder, please let us know.



Mr. Tadayuki Kurita
Sales Group,
Electric & Electronics Products Division
Aichi Electric Co., Ltd.

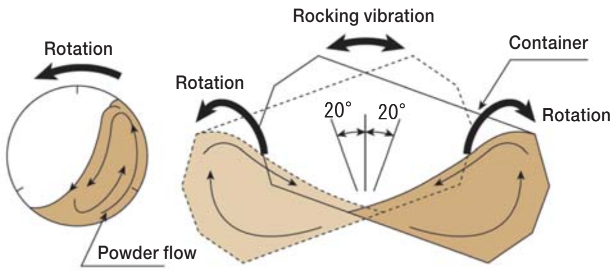


Fig. 2 Container rocking/rotating mechanism

Could you tell us about the background of introducing powder mixing simulation with Granuleworks(1)?

Our "Rocking Mixer", the rocking/rotating dry powder mixer is the machine that has our unique mechanism performing complex rotational rocking motions as shown in **Fig. 2**, characterized by soft mixing, easy washing, removable containers, and inclined rotary discharge, etc. The target industries are foods, medicines, ceramics, resins, metals, etc. And thus, it is widely used in raw material mixing processes in a wide range of industries. Initially when this machine was developed in 1981, it was used as a device to mix seasoning. At that time, we carried out trial and error to see how to mix evenly, and we noticed that rocking and rotating the container at the same time makes it possible. By keeping the basic mixing mechanism and container shape, we have continued to make improvements little by little.

We conduct magnetic field simulations and fluid flow simulations utilizing computer technology for preliminarily studies of product design of transformers and motors. However, for powder equipment, we are designing products based on actual measurements and experience. Since our customers handle a wide variety of powders, when they consider the purchase of our machines, we ask a mixing ability test with an actual machine of our standard specifications. It is good when the customer is satisfied with the result of the test, but sometimes that is not the case. In such cases, we conduct a test again by changing the operating conditions and the container shape. We repeat this until the customer is satisfied and then we decide on the product design conditions. Since such tests are time-consuming and expensive, it is desirable to minimize the number of times we have to carry out such tests, and we strive to reduce the number of tests by guessing the optimum conditions according to the experience of the person in charge. When we were considering whether we could infer the optimum conditions using the simulation technique during the preliminary examination of the test, we knew that Prometech would be able to commercialize Granuleworks, so we decided to use the prototype. First, after performing mixing simulations with Prometech, we rented Granuleworks and confirmed usability and analyzed the simulation results in detail. I have no experience in simulation work, but I felt that amateurs like me could use this conveniently. We now use simulation results to improve product PR and mixing ability.

Please give us some examples of simulations using Granuleworks.

We analyzed the mixing phenomenon performed by the "Rocking Mixer", compared the actual machine and the simulation using the mixing degree and still images, analyzed the simulation results in detail, and investigated the movement of the powder during mixing. First of all, we decided the physical property values of powder as preparation for simulation. The physical properties of powder that greatly influence the mixing in the "Rocking Mixer" are particle diameter, particle density, friction coefficient, and rolling coefficient. The rolling coefficient is a unique property value of Granuleworks, indicating the ease of rolling particles. The powder is easier to roll as the shape approaches a spherical shape, and on the contrary, if the shape is distorted, it becomes less likely to roll. The particle shape calculated by simulation was spherical, but by adjusting the rolling coefficient, it became possible to calculate the cases of particles being not spherical. Particle diameter and particle density can be measured using a general-purpose measuring instrument, but there is no such instrument for measuring the friction coefficient and rolling coefficient. Therefore, the friction coefficient was determined by measuring with a self-made device. As shown in **Fig. 3**, the self-made measuring device is used by fixing particles to the plate with an adhesive so they do not roll, and measuring the friction angle by placing the plate on a tilt table. The inclination angle at which the plate starts moving is the static friction angle, and the inclination angle at which the moving plate stops is the dynamic friction angle. The friction coefficient was determined by derivation from the friction angle.

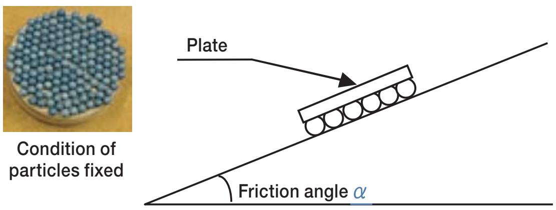


Fig. 3 Device for measuring friction angle

There is no measurement method for the rolling coefficient. Because the ease of powder rolling greatly influences the formation of repose angle, the rolling coefficient was determined by deriving a value that agrees with the experiment result of repose angle and the simulation result as shown in **Fig. 4**. At that time, the values of particle diameter, particle density and friction coefficient were fixed, and only the value of the rolling coefficient was adjusted. The reason why the simulation particle is bigger than that of the actual machine is that the number of particles calculated is reduced by coarsening the particle by utilizing Prometech's proprietary technology SDEM[2] is reduced, thereby shortening the calculation time. As a result of the comparison, I was impressed that the shape and height of the heaps of the particles were almost identical.

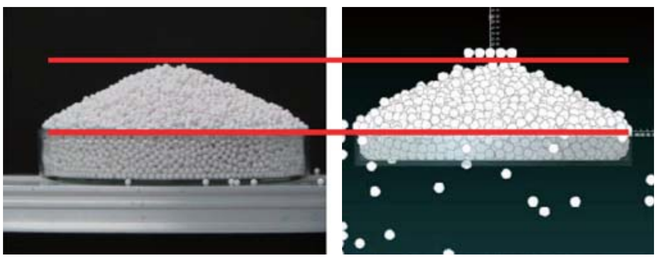


Fig. 4 Comparison of repose angle in test and in simulation

The experimental equipment used for analyzing the mixing phenomenon was a "Rocking Mixer" equipped with a 10L capacity hard glass container and a mixed sample of alumina balls of ϕ2mm and ϕ3mm. The ball of ϕ2mm in diameter was colored blue for visualization. In order to shorten the calculation time, we made the sample 1.5 times coarser with the above-mentioned SDEM and reduced the number of particles from 280,000 to 46,000. The simulation model had the same shape as the experimental equipment. **Fig. 5** shows a simulation model showing the container shape and particle loading state, and **Fig. 6** shows a comparison between the experiment and the simulation, after inserting powder and when it is inclined by 20° before starting mixing simulation. The inner wall of the cylindrical container has a structure with three blades installed to promote mixing. These blades are a feature of our product, and powder will slip near the surface without them. We also know that the height, thickness and number of blades affects mixing, but this time we do not calculate it. That is a challenge for the future.

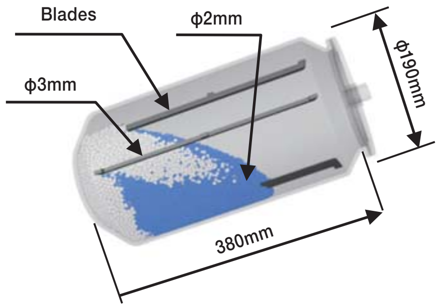


Fig. 5 Container shape and loading state

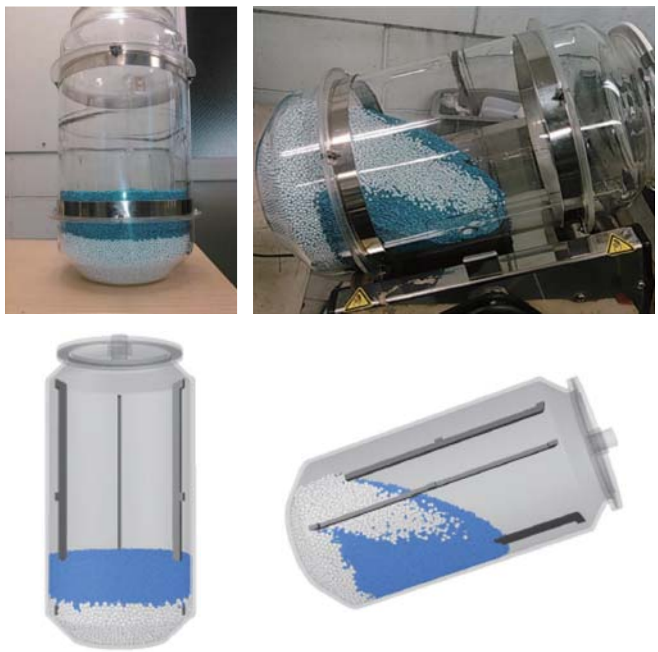


Fig. 6 When loading powder, and at 20°inclination before starting mixing: comparison of experiment (left) and simulation (right)

Regarding the degree of mixing and its condition, we compared experiments and simulations. As for the degree of mixing, as shown in **Equation 1**, samples are taken from 6 locations in the container at each elapsed time, and standard deviation focusing on the weight of ϕ 2 mm alumina balls included in the sample is calculated by dividing the theoretical weight ratio. **Figure 7** shows the comparison of the degree of mixing between the experiment and the simulation. The measurement of the degree of mixing in the experiment was carried out four times to include variability, and its variability range was indicated by the maximum and the minimum values. Regarding the degree of mixing measurement, sampling was carried out every 20 seconds from the beginning to 1 minute, and then every 1 minute thereafter. There was a gap in 20 seconds of initial movement, but thereafter it was confirmed to be mostly accurate.

$$y = \frac{a}{a+b} \qquad ①$$

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{n=1}^{n}}\ (y - Y)^2 \qquad ②$$

$$M = \frac{\sigma}{Y} \qquad ③$$

a：Weight of particle diameter ϕ2 ㎜ ball in the sample [g]
b：Weight of particle diameter ϕ3 ㎜ ball in the sample [g]
y：Weight ratio of particle diameter ϕ2 ㎜ ball in the sample
Y：Theoretical weight ratio of particle diameter ϕ2 ㎜ ball
σ: Standard deviation of particle diameter ϕ2 ㎜ in the sample
M：Degree of mixing

Equation 1 Formula for calculating degree of mixing

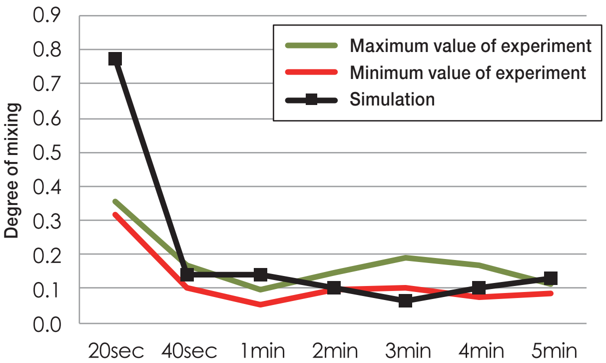


Fig. 7 Comparison of mixing degree between experiment and simulation

Fig. 8 shows the comparison of mixing condition at each position between experiment and simulation at the same time. These are presentative images of mixing during rocking vibration, and we compared the second cycle of the vibration process. It was confirmed that the condition of the existing patterns of blue particles and white particles and their boundary are quite close.

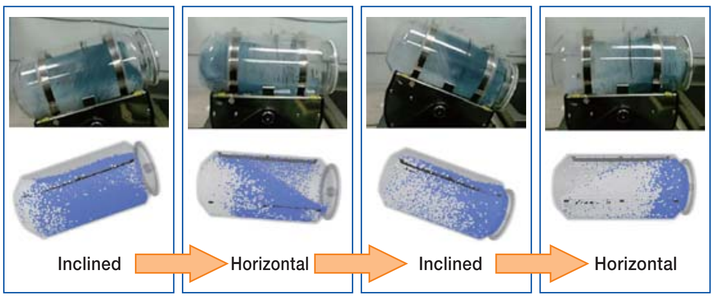


Fig. 8 Comparison of mixing states at each position in the beginning of mixing

So, we judged that the experiment and the simulation are close from the result of mixing degree comparison and the mixing condition. Based on this, detailed simulation was carried out. **Fig.9** is the visualization results of powder trajectory in this container. For this evaluation, we focused on two types of particles: ① and ②.

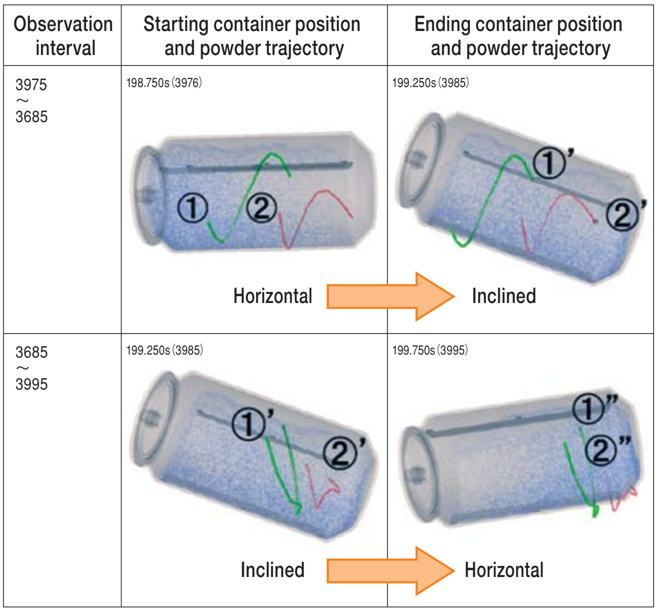


Fig. 9 Visualization of powder trajectory

In addition, we visualized the translational velocity of particles, the angular velocity and the physical quantity of stress during mixing from simulation results. At that time, particles with large physical values are colored in gradational red and particles with small values are colored in gradational blue. **Fig.10** shows the visualization results of the moving speed and the rotation speed at the same time. It was confirmed by this visualization that the moving speed is faster in the outer periphery and in the vicinity of the blade, and that the rotation speed is faster in the central part. There are two types of mixing: moving mixing, in which particles move largely inside the container, and diffusion mixing, in which the particles rotate and move while exchanging positions. From the results of this visualization it can be inferred that moving mixing occurs at the outer periphery and diffusion mixing occurs at the central part. **Fig. 11** shows the stress applied to the powder. It was confirmed that the stress was increased at the bottom of the container and above the blade. This is presumed to be the influence of particle weight. It is preferable to have less stress to mix without breaking particles. In our mixer, it is assumed that mixing is carried out so that particles are not easily broken, as stress above the weight of the powder is not applied

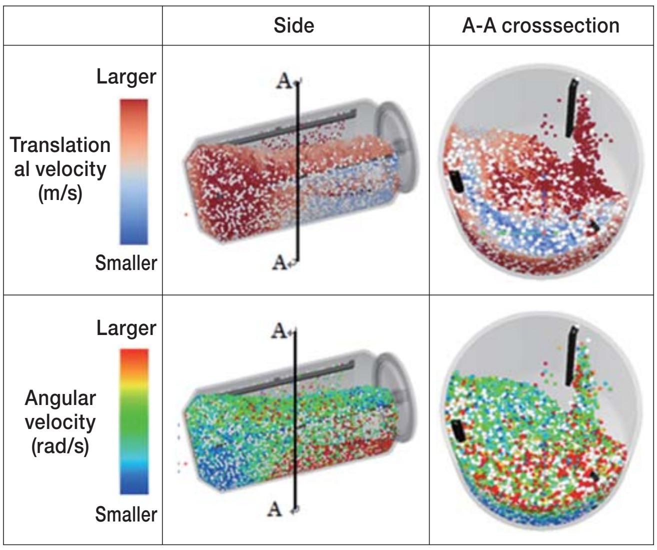


Fig. 10 Translational velocity and angular velocity

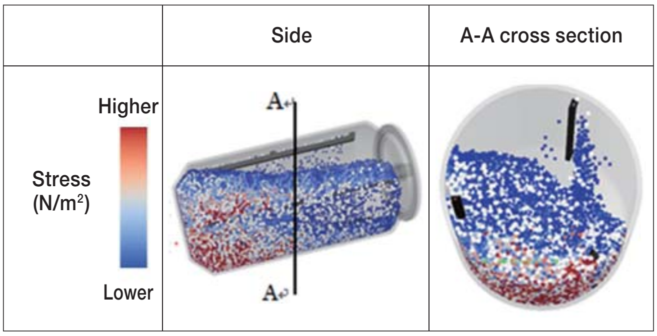


Fig. 11 Stress

Please tell us your future expectations and requests for Granuleworks.

First of all, I expect that using Granuleworks will reduce the testing time of actual machine. Actual powder materials are sometimes very expensive and difficult to obtain, so if we can reduce tests by predicting the mixing result in advance, we could lighten the burden on our customers. We also expect Granuleworks to shorten the equipment design and development period. In designing the concept, if you can predict the optimum condition by simulation beforehand, it will lead to cost savings by not only shortening the period but also reducing prototype production. I also think that utilizing such a simulation would be useful for understanding powder technology, which is very important for the engineers. I think that it will be a tool with which to understand the fundamentals about what the powder phenomenon is, and to visualize, digitize, and develop the conventional rules of thumb. Also, I expect that the process of visualization can be useful for ideas leading to the development of new products. I hope that it will eventually be useful in improving the products PR.

The first request we have for Granuleworks is reducing the work time and the calculation time to determine physical property values. Another request is to expand the scope of applications, not only of powders but also coupled simulation of gases and solids, liquids and solids, and heat simulation. If we can analyze the stress applied to the container, we can use it in strength design of mixers. I hope that these will be improved and that the range of application will be extended.

We are thankful for your cooperation in this interview and for giving your valuable opinions today. Here at Prometech, we will continue to support you in the future to continue developing better products.

Reference
Prometech Summer Seminar 2017 in NAGOYA (July 4, 2017) Lecture Materials
Note (1): Granuleworks mentioned above is the one as of July 2017, which is a prototype version available before its official release. For details of the function, please contact us.
Note (2): SDEM is planning to be released in Granuleworks V.1 as a minor version upgrade.

Interviewed on July 4, 2017

AICHI ELECTRIC CO., LTD.

Aichi Electric Co., Ltd.

Address: Kasugai City, Aichi Prefecture
Established: May 27, 1942
Businesses: Power business relating to transformers, control/communications, power conversion, environment, etc., and machine business relating to motors, mechatronics, environment and control, etc.
Website: http://www.aichidenki.jp/english/product/rm/index.html

Contact

PROMETECH

Prometech Software, Inc.

Head Office
Hongo Dai-ichi Building, 8th Floor, 34-3,
Hongo 3-chome, Bunkyo-ku, Tokyo 113-0033, Japan
Tel: +81-3-5842-4082 Fax: +81-3-5842-4123
West Japan branch office
Asahi Kaikan, 7F, 3-3, Sakae 1-chome,
Naka-ku, Nagoya, Aichi 460-0008, Japan
Tel: +81-52-211-3900 Fax: +81-52-211-3901
URL: www.prometech.co.jp
E-mail: sales@prometech.co.jp