A Numerical Study for Rice Using Distinct Element Method

Tomoyuki Miyamoto [1], So Noguchi [1], Shinya Matsutomo [2]

[1] Graduate School of Information Science and Technology, Hokkaido University, Japan

[2] Department of Electronic Control Engineering, Niihama National College of Technology, Japan

1 Introduction

In this paper, we discuss the fundamental simulation data of a rice processing machine for optimum planning, effective designing and cost-reduction. Rice variously and complicatedly behaves in the processing machine because the amount of water, the degree of adhesion, and the grain size are various and depending on a breed in the rice, even if the rice grains have a same shape. The above affects the performance of the rice processing equipment. In this study, a numerical simulation is carried out using three-dimensional Distinct Element Method (DEM) based on the measured angle of repose in each rice breed in order to highly accurately reproduce the behaviour of rice in the processing equipment as an Optical Sorter.

2 Distinct Element Method

The DEM is a numerical method used for computing stresses and displacements in a volume containing a large number of particles such as grains of sand [1]. Granular material is modelled as an assembly of rigid particles and interaction between each particle is explicitly considered (shown in Fig. 1). Here, in the effects of normal and shear directions, K_n and K_s are the elastic stiffness, η_n and η_s are the viscous damping and μ is the friction slider. The particle shapes and geometries are specified by a user. Sphere shape is commonly employed.

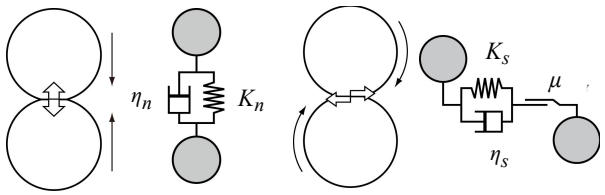


Fig. 1. Contact Model for DEM.

3 Agenda Details

3.1 Characteristics of Rice

There are Long Grain, Middle Grain, and Short Grain in the kinds of rice. Moreover, they are classified into Non-glutinous Rice and Glutinous Rice according to starchiness. What has the best rice harvest in the world is the Long Grain Non-glutinous Rice. The Long Grain is the rice that the length is more than 6.6 mm and the aspect ratio (length/width) is less than 3.0. Raw Rice and Parboiled Rice belongs to the Long Grain. The Raw Rice is what has simply milled Paddy, and the Parboiled Rice is what has milled just as Paddy after steaming and drying the rice. The character of the Raw Rice is much different from the Parboiled Rice (shown in Table 1). Irrespective of same-shaped rice, the Parboiled Rice has a higher angle of repose than the Raw Rice's because the rice surface adhesion is high by steaming process.

Table 1. Angle of Repose in Rice.

Variety	Angle of Repose
Long Grain Raw Rice	40-42 degree
Long Grain Parboiled Rice	45-47 degree

3.2 Subject Outline in Optical Sorter

Commonly, a rice processing equipment has an Optical Sorter. The Optical Sorter is the machine that sorts discolored rice and foreign material like a stone and a glass by recognizing them with a high-performance camera, and blows away the foreign particle with an ejector like an air-gun. Fig. 2 shows the schematic view of the optical sorter. There are three processes in the equipment. First, the material is supplied with a chute. Second, good particles or bad particles are recognized with the high-performance camera. Third, the bad particles are sorted with the ejector. As technical advantages of the optical sorter it is necessary to supply the material to sensing station with constant speed and suitable density. Thereby, the influence of skin friction for the chute surface is reduced. However, the chute structure is very simple, therefore it is impossible to regulate the flow of material.

Especially, the flow of the Parboiled Rice is uneven and agglomerated on the chute. These behaviour causes to deteriorate the sorting performance (quality, amount of throughput, yield rate). The Raw Rice and the Parboiled Rice flowing on the chute are shown in Fig. 3, which were captured by the camera of the Optical Sorter.

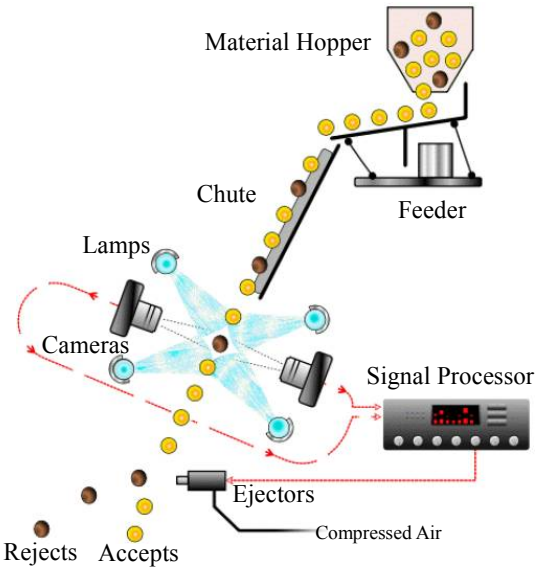
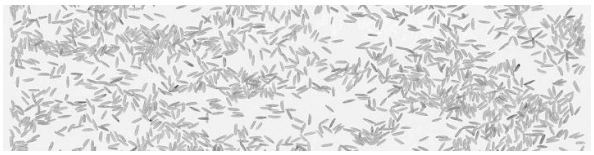


Fig. 2. Schematic View of Optical Sorter.

Raw Rice



Parboiled Rice

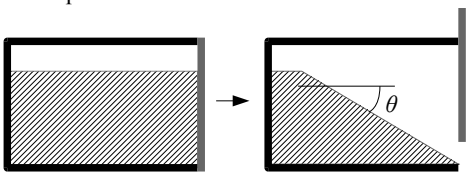
Fig. 3. Captured Images by Optical Sorter.

4 Verification Approach by Numerical Simulation

4.1 Simulation Models

Firstly, we carried out a virtual simulation of the angle of repose for the Raw Rice and the Parboiled Rice. The difference between them is produced by the elastic stiffness, the viscous damping, and the friction slider of the parameter in the DEM. The simulation model is the Ledge Method in a measurement method of the angle of repose (shown in Fig. 4). The material is initially charged into a rectangular box. A slot at the base of one vertical wall is closed by a board. The closure board is then removed to allow the material to flow slowly through a narrow slot. The angle of the horizontal plane of the surface of the material equilibrium is measured when the flow stops [2].

Secondly, we carried out a virtual simulation of the material flowing on the chute of the Optical Sorter with these parameters. These are compared with the actual behaviour of rice.



θ : Angle of Repose

Fig. 4. Simulation Model for Angle of Repose.

4.2 Simulation Results

The angle of repose for the Raw Rice and the Parboiled Rice was virtually simulated (shown in Fig. 5). We figured out that the angle of repose was particularly affected by the viscous damping of the parameters in the DEM. In addition, the rice flowing on the chute of the Optical Sorter was also virtually simulated by the DEM with the particles of spheres (shown in Fig. 6).

5 Conclusion

In this study, the numerical simulation was carried out using the three-dimensional Distinct Element Method based on the measured angle of repose in each rice breed in order to highly accurately reproduce the behaviour of rice in the Optical Sorter. We figured out that the DEM is effective in the development of the Optical Sorter. In future prospects, the particle shape of the DEM will be extended from sphere to particle consisting of some sphere or ellipsoid in order to model the real shape of the rice. Moreover, we will discuss the effective designing to improve the behaviour of the Parboiled Rice in the Optical Sorter.

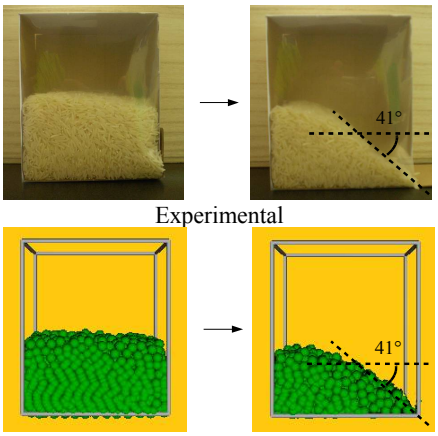
Acknowledgements

We appreciate that SATAKE Corporation has suggested the subject of this research and provided the valuable information of the rice.

References

[1] Tej B. S. Pradhan, S. Sawada, Distinct element analysis of sand under cyclic loading using oval elements, Proc. of 10th WCEE, pp.1163-1168, 1992

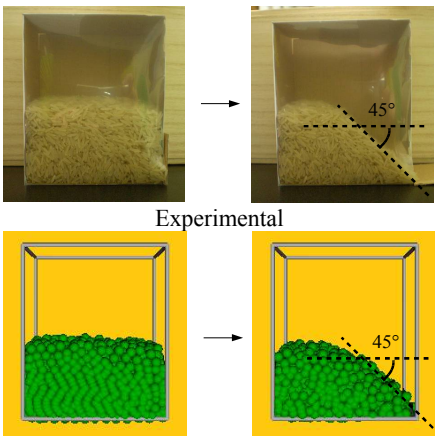
[2] Oleg D. Neikov, Stanislav S. Naboychenko, Gordon Dowson, Handbook of Non-Ferrous Metal Powders: Technologies and Applications, Elsevier Science, USA, pp.39, 2009



Experimental

Simulated

Raw Rice

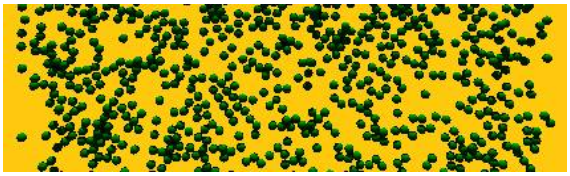


Experimental

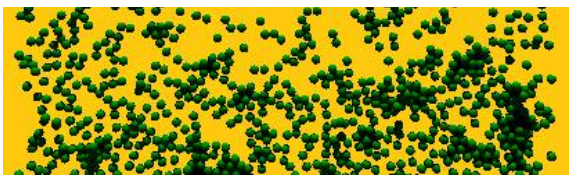
Simulated

Parboiled Rice

Fig. 5. Simulation Results for Angle of Repose.



Raw Rice



Parboiled Rice

Fig. 6. Simulation Results for Optical Sorter.