Research on wheat modeling method based on EDEM

Song Chen¹, Shukun Cao¹*, KuiZeng Gao², WenLong Cao², Shoubo Cui² and Jianzhong Ma²

¹School of Mechanical Engineering, University of Jinan, Jinan, Shandong, 250022, China
²Shandong Juming Machinery co. LTD, Zibo, Shandong, 256400, China
*chensong666@mail.ujn.edu.cn

Abstract. Based on the actual shape of the wheat, the size of 50 wheat grains was measured, and the average value was used to construct a three-dimensional map. Then, the sphere of 0.2mm is filled automatically in the API of discrete element software, and the model is compared with the filling model included in the software. The method of bottomless cylinder stacking angle is used to simulate and compare with the actual experiment. The results show that, compared with the actual test results, the error of API automatic filling model and manual filling model is 3.08% and 14.00% respectively. This result proves that the model of API automatic filling is closer to the wheat grain in real life.

1. Introduction
Discrete Element Method (DEM for short) is a numerical method suitable for studying the motion behavior of discrete bodies[1]. The shape of wheat grains is mostly irregular. In discrete element simulation, the particle model is an important parameter that affects the results. In discrete element software, particle filling is usually the first step to define the small spheres that need to be filled with the particles, and then place these small spheres in different coordinate positions to fill the particles[2]. Generally, the grains produced in the filling process of discrete element software are too regular to fit the grain contour completely, and can not simulate the collision and rolling characteristics of wheat grain under actual conditions[3]. There are also essential differences between particles and real particles, so how to generate a particle model through an appropriate method is very important[4].

2. Establishment of Discrete Element Model of Wheat Grain

2.1. Establishment of three-dimensional model of wheat grain
The wheat variety Shannong No.27 was selected in this paper. In order to establish the three-dimensional model of wheat grain, 50 wheat grains were randomly selected from the harvested wheat grains. The data of length, width and thickness were measured with vernier caliper, and the average grain diameter of 50 wheat grains was taken. The three dimensions of the three-dimensional model of wheat grains that need to be established are: length 6.76 mm, width 2.98 mm and height 2.88 mm. Based on the average size of wheat grains that have been obtained, a corresponding three-dimensional model is constructed with Solidworks, as shown in Figure 1.
2.2. Discrete Element Model of Wheat Grain

2.2.1. Manually fill the wheat grain model. This part saves the 3D wheat grain model created by Solidworks in the .x_t format, and then imports it into EDEM for grain filling. The manual filling wheat grain model consists of 13 particle surface balls. The position of the 13 particle surface balls is determined by setting the parameters of the radius of the 13 particle surface balls and the X, Y and Z parameters of the center of the sphere, thereby achieving the purpose of filling the particle template. The filled wheat grains are shown in Figure 2 (a) (b).

2.2.2. API filled wheat grain model. The modeling method used by EDEM software is generally a multi-ball combination to fill the irregular particles, and the multi-ball model uses templates to assist in the creation of particle prototypes. The larger the number of spheres filled in the template and the smaller the radius, the more accurately the shape and contour of the real wheat grains can be restored. However, considering the computational complexity of computer simulation, the number of spheres will be controlled within a certain range [5]. In this study, the radius of the filled sphere is 0.2mm. First of all, in the Globals and Particles interface of the pre-processing Creator in EDEM, set the material, gravity, friction and other parameters that need to be filled with the ball. Because it needs to be filled quickly, you can set the gravity to be larger and smaller. The collision recovery coefficient and the dynamic and static friction coefficient make the spherical particles have better fluidity. The particle contact mode is set to the Hertz-Mindlin non-slip contact model. Secondly, import the .x_t file of the 3D wheat grain model created by Solidworks in the Geometry interface, and select its material. Finally, select the 3D wheat grain model as the pellet factory in the Factories interface. The pellet factory type is dynamic generation, the number of particles is set to an unlimited number, and the particle generation speed is the default speed. Then switch to the Simulator interface to set the simulation time step and other parameters, and start the simulation. When the sphere is completely filled with the wheat grain template and no longer moves, the X, Y, and Z values of all the spheres are set in the post-processing interface of EDEM. Export the data of Z and the radius of the ball to a .csv file. Then use the API function outside EDEM to compile an .xml file through vs2013, then create a new file in EDEM, import the .xml, and save it as a .dem file. The EDEM software will automatically generate a corn kernel model according to It can be used directly as a particle template. The final API filling model for wheat grains is shown in the figure 2.
3. Test verification

Accumulation angle (angle of repose or natural slope angle): refers to the maximum angle between the surface of the bulk material pile that is naturally formed on the plane and the horizontal plane. It is a macroscopic parameter that characterizes the flow and friction of the bulk material particles. Generally, the discrete element simulation of crop seeds uses the stacking angle method to conduct experiments, because the method is convenient and simple to operate, and the results show obvious advantages and are widely used.

3.1. Stack angle test method

The bottomless cylinder method is used to measure the accumulation angle of wheat grains through real experiments and EDEM simulation experiments. Put a bottomless cylinder horizontally on the table, and then fill the cylinder with the wheat grains to be tested and place it vertically by hand. Lift the cylinder slowly in the direction to overflow the wheat grains. When the cylinder is lifted to a certain distance, the wheat grains in the cylinder will completely overflow, forming a stacking angle, that is, the cone of the cone. The angle with the horizontal plane. According to literature review, the ratio of the height of the cylinder to its diameter should be 3:1, and when the granular grain is less than 15mm, a bottomless cylinder with a diameter of 50mm and a length of 150mm is usually used. In order to ensure the accuracy of the test, wheat grains of the same size cylinder, the same lifting speed and the same quantity are used in the actual test and the EDEM simulation test.

3.2. Discrete element simulation experiment of wheat grain pile-up angle

3.2.1. Related simulation parameter settings. By consulting domestic and foreign related literature on wheat grain and barrel materials, the following simulation parameters are obtained, as shown in Table 1 and Table 2.

| Materials | Poisson ratio | Shear modulus(MPa) | Density(kg·m⁻³) |
|-----------|--------------|--------------------|----------------|
| Grain     | 0.3          | 2.6                | 1350           |
| Device    | 0.3          | 700                | 7800           |

| Contact form | Coefficient of restitution | Coefficient of Static friction | Coefficient of rolling friction |
|--------------|-----------------------------|-------------------------------|--------------------------------|
| Grain-grain  | 0.2                         | 1.00                          | 0.01                           |
| Grain-device | 0.5                         | 0.58                          | 0.1                            |

3.2.2. Simulation analysis. First, in the Particles section of the preprocessing interface in EDEM, import the wheat grain model that was created before and transfer to the Geometry section to create a bottomless cylinder model with a diameter of 50mm and a length of 150mm and a plane under the bottomless cylinder. Secondly, a circular grain factory is built above the bottomless cylinder to generate wheat grains to fill the entire bottomless cylinder. Finally, go to the simulation Simulator interface and set the simulated Fixed Time Step to 30%, and set the grid Cell Size to 30 R min, and the simulation time Total Time to 5s. After the setting is completed, perform the simulation. After the particles completely fill the bottomless cylinder, pause the simulation and go to the Geometry section under the preprocessing interface. Set the bottomless cylinder speed to 0.05m/s and the direction to - Z, then continue the simulation and wait for the simulation to finish. The simulation process is shown in Figure 3. In the same way, the particle simulation steps using API filling are the same as above.
3.2.3. Simulation result analysis. After the two simulations are completed, measure the pile-up angle of the wheat grains after the simulation, and use the angle measurement tool Protractor in the EDEM software to analyze the pile-up images to obtain the pile-up angle of the wheat grains. Since the wheat grain contact surface is replaced by a spherical surface in the EDEM software, the two models have different radii and numbers of filled spherical particles, and the forces between the particles will be different, so the results of the two simulations will be different, that is, the two simulations The stacking angle is different.

3.3. Realistic experiment of wheat grain pile-up angle
The selected wheat is Shannong 27 winter wheat, and the bad wheat that is not full, incomplete and moldy in the wheat is picked out so as to be consistent with the conditions of the previous simulation experiment. Pour the selected intact wheat into the test cylinder and make it fill the cylinder, then slowly lift the cylinder by hand. The wheat grains in the cylinder will flow out under the cylinder under the action of gravity. When it is stable, the corn kernels form a pile angle, the process is shown in Figure 4. In order to test the accumulation angle of wheat grains, the accumulation angle is calculated by measuring the accumulation radius and height and carrying out arctangent, and taking multiple measurements to get the average value.

3.4. Test analysis
The wheat grains formed by filling with EDEM's own balls are called grain A, and the wheat grains formed by API automatic filling are called grain B. In order to make the test data accurate, the simulation test with self-filled function, the simulation test with API automatic filling and the actual test were performed 5 times respectively, and the test design table was made, as shown in Table 3.

| Test number | Wheat A | Wheat B | Real test |
|-------------|---------|---------|-----------|
| 1           | 24.59   | 27.85   | 28.07     |
| 2           | 23.72   | 27.94   | 28.98     |
| 3           | 25.21   | 29.24   | 28.54     |
| 4           | 24.56   | 28.45   | 27.94     |
| 5           | 24.68   | 28.32   | 29.22     |
| Average     | 24.55   | 27.76   | 28.55     |
| SD          | 0.53    | 0.69    | 0.56      |
| Error/%     | 14.00   | 3.08    |           |

Table 3. Mechanical properties of wheat grain and device
From the above table, it can be seen that the error of grain A is smaller than that of grain B, that is, the wheat grain model constructed by the small ball filling that comes with the discrete element software does not have the wheat grains constructed by API automatic filling. Close to the real situation. Because, for the wheat grains filled by API, the balls are filled according to the three-dimensional map of the grains during the filling process. The balls fully reflect the complex contours of the wheat grains, which cannot be achieved by the built-in filling mode of the discrete element. Therefore, the heap angle of wheat grains filled with API is closer and more realistic than the actual heap angle of wheat grains. The final result of the simulation can also be seen, as shown in Figure 5.

![Figure 5. Realistic test process](image)

4. Conclusion
In order to verify that the grain model automatically filled by the discrete element software API is closer to the real wheat grain, this paper first measured the grain size of 50 wheat grains through the shape of real wheat, and took the average value to construct the three-dimensional map of wheat grain. Then, the API automatic filling, 0.2mm ball filling, the built model and the filling model attached to the software were simulated by using the method of bottomless cylinder stacking angle, and compared with the actual experiment. The conclusions show that the errors between the model formed by API automatic filling and the model formed by the software's own filling and the actual test are 3.08% and 14.00%, respectively, which proves that the grain model formed by the automatic filling of the discrete element software API can be closer to the real life.

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