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# Discrete Element Simulation Analysis of Vibratory Cleaning Device

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**Abstract:** The corn cleaning device is the most critical component of the corn harvester. It has an important relationship with the loss rate and impurity rate of corn. Therefore, it is of great significance to study the corn cleaning device and cleaning process to improve the mechanization level of corn harvest and promote the development of Agricultural Mechanization in China. In this paper, a vibratory cleaning device is designed, and the working mechanism of the device is introduced. The discrete element method is used to simulate the vibration cleaning device, and the movement status of the corn prolapse during cleaning is analyzed. The speed change of corn prolapse during cleaning is also analyzed.

## 1. Background and significance

China is a country that produces a lot of corn, but the mechanization level of maize harvest is relatively low. According to the statistics of the related data, the mechanized harvest level of corn in 2013 is only 49%, while the mechanized harvest of rice is 73%, and the mechanized harvest of wheat is 92%[1]. The quality evaluation technical specification of corn combine harvester stipulates that the loss rate of corn should be less than 2% in the process of corn cleaning[2]. At present, the technology of corn harvester is unskilled in our country, and the corn harvester that cannot reach the technical standard still occupies a large proportion.

Most of the researches on the process of maize cleaning at home and abroad, mostly use the method of test, statistical analysis or traditional continuous medium mechanics analysis method [3], but the traditional methods have many problems, such as time-consuming and laborious, poor generality and so on. The simulation analysis of corn cleaning device based on the discrete element method cannot only make us understand the working mechanism of the corn cleaning device, but also provide a theoretical basis for optimizing the structure of the corn cleaning device, and it is of great significance to improve the cleaning rate and lower the loss rate of the corn grain during the cleaning process.

(1)It cannot only promote the early realization of mechanization of maize production in China, but also verify the accuracy of the discrete element method in the simulation analysis of corn cleaning process.

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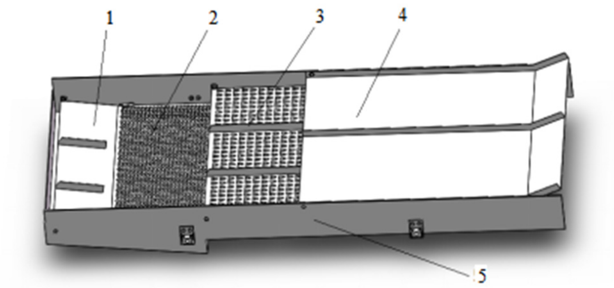
(2)It not only enriches the discrete element method, but also has reference value for future research on other crops cleaning process.

(3)It can intuitively observe the working mechanism of the cleaning device, the movement of the corn prolapse, and overcome the shortcomings of the long cycle and low efficiency made in the traditional mechanical design process, and achieve the purpose of saving the cost.

## 2. The vibratory cleaning device

There are many kinds of corn cleaning equipment. According to the number of vibrating screens, they are divided into single screen cleaning device and multi-layer screen cleaning device. In this paper, a multi-layer vibration cleaning device is designed, which includes four screen bodies: tail sieve, circular hole sieve, louver sieve and wave sieve, as shown in Figure 1. The length of the vibrating cleaning device is 2720mm, the height is 420mm, and the width is 1000mm. The top of the vibration cleaning device is wave sieve, its surface is relatively smooth, and there is a partition in the middle. The length of louver sieve is 1000mm and the thickness is 3mm. The shape of the sieve hole is similar to the shape of the fish scale, and it can reduce the screening rate of the broken cob and other impurities. It has a good ability to push the corn out of the back, and the sieve hole is not easily blocked. The quality of the sieve is small and the structure is simple. It can be used for roughing and selection. The length of the circular hole sieve is 1000mm, and the thickness is 3mm. The diameter of the sieve hole is 15mm, which is directly punching out of the punch. The shape of the sieve hole is round, the diameter is slightly larger than that of the corn kernel, and the screening performance is better.There is no sieve hole above the tail sieve and the wave sieve, which are used to push materials. The layout of the four sieve bodies of the corn cleaning device has a relatively interlaced spatial position.




1.tail sieve 2.circular hole sieve 3.louver sieve 4.wave sieve 5.sieve body

Figure 1 Vibratory cleaning device

## 3. The models of corn prolapse

The corn prolapse is a mixture of corn plants after picking, feeding, conveying and threshing the corn harvester and finally falling into the cleaning device. The main components of corn prolapse are corn kernels, broken corncobs, broken corn stalks and some light impurities (the main components are fine stems and leaves and corncob residue). The proportion of light impurities is very small and does not affect the simulation results. Therefore, we do not consider the light impurities, only model the corn kernels, the broken corncobs and the broken corn stalks.

The models of corn prolapse is shown in Figure 2. The shape of corn kernels is similar to that of cones, with a length of 10.14mm, a width of 7.64mm, and a thickness of 4.06mm. 13 spherical particles are used to fill the model. The maximum particle radius in these particles is 2mm, and the radius of the smallest particle is 1mm. The shape of broken corn stalks is similar to a cylinder, with a diameter of 8mm and a length of 45mm. 9 spherical particles of the same size are used for filling modeling. The shape of the broken corncobs is similar to that of cuboid, with a length of 18mm and a width of 16mm. 56 spherical particles are used to model the maximum particle radius of 4mm and the minimum particle radius of 2.5mm. 56 spherical particles are used to establish the model. The maximum particle radius of these particles is 4mm and the minimum particle radius is 2.5mm.

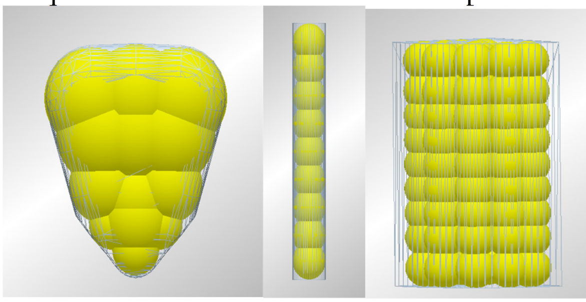


Figure 2The models of corn prolapse

## 4. Simulation setting

*4.1 Parameters setting of corn prolapse*

When using the discrete element software EDEM to model the corn prolapse, it is necessary to set up the mechanical parameters of the corn prolapse, including the Poisson's ratio, the shear modulus and the density. The Poisson's ratio of corn kernels, broken corn stalks, broken corncobs and sieve surface are 0.4, 0.42, 0.45 and 0.3 respectively. The shear modulus of corn kernels, broken corn stalks, broken corncobs and sieve surface are 0.127GPa, 0.1GPa, 0.109GPa and 70GPa respectively. The densities of corn kernels, broken corn stalks, broken corncobs and sieve surface are 1197kg.$m^3$, 112kg. $m^3$, 330kg. $m^3$ and 7800kg. $m^3$ respectively.

In the sieving process, it is inevitable that there exists a collision and friction between the corn prolapse and the cleaning device. Therefore, the contact parameters between the corn prolapse and the vibrating screen are set up, as shown in Table 1.The contact parameters of corn prolapse include coefficient of restitution, coefficient of static friction and coefficient of rolling friction[4]. The coefficient of restitution of corn prolapse refers to the ratio of the velocity of corn prolapse after the collision with the vibrating screen to the velocity before collision. The coefficient of restitution of corn prolapse can also be used to indicate the energy loss before and after the collision of corn prolapse. The coefficient of static friction of corn prolapse can be measured by inclined plane mechanics. As the main movement of the corn prolapse in the cleaning device is not rolling, the default value of the EDEM software is selected according to the selection principle of the coefficient of rolling friction[5]. The default Hertz-Mindlin (No Slip) non slip contact model in EDEM software is used as a particle contact model.

Table 1 The contact parameters between materials

| Material | the coefficient of restitution | the coefficient of static friction | the coefficient of rolling friction |
|---|---|---|---|
| corn kernels-corn kernels | 0.31 | 0.79 | 0.01 |
| corncobs-corncobs | 0.22 | 0.78 | 0.01 |
| corn stalks-corn stalks | 0.21 | 0.65 | 0.01 |
| corn kernels-vibrating screen | 0.54 | 0.48 | 0.01 |
| corncobs-vibrating screen | 0.33 | 0.7 | 0.01 |
| corn stalks-vibrating screen | 0.29 | 0.62 | 0.01 |
| corn kernels-corncobs | 0.25 | 0.68 | 0.01 |

*4.2The geometry model setting*

The three-dimensional model of vibratory cleaning device set up by SolidWorks software is saved as IGS format, which is introduced into EDEM software, and the geometric model of the cleaning device is established, as shown in Figure 3. The frequency of the vibration cleaning device is 4Hz, the amplitude of the X direction is 110mm, the amplitude of the Y direction is 11mm, and the vibration direction angle is 35 degrees.

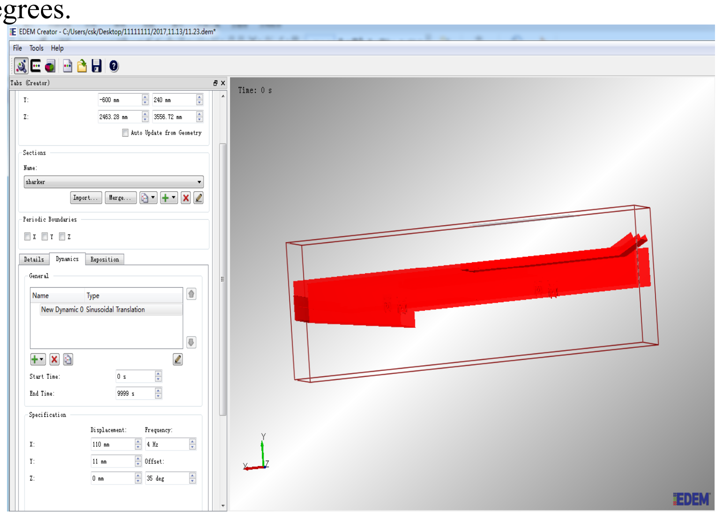



Figure 3 The geometry model of cleaning simulation

As the motion of the various parts of the vibratory cleaning device is consistent, when the vibratory cleaning device is imported into the discrete element software, the entire components of the cleaning device can be integrated through the Merge Setions in Import Options, as shown in Figure 4.By the working mechanism of the vibrating cleaning device, it can be seen that the cleaning device is a simple harmonic motion of repeated motion. Therefore, the details of the geometric model are set to Sinusoidal Translation, its material property is steel, and the type is physical.

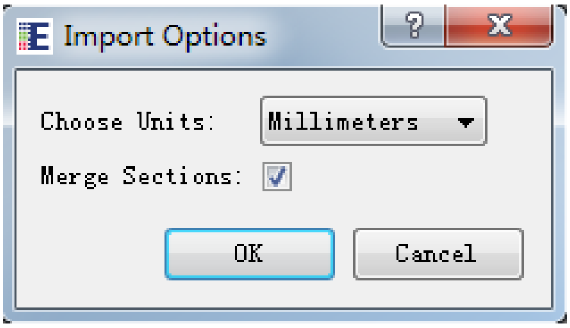



Figure 4 Import Options

The particle factory is used to define the appearance, time and location of particles in the simulation. Each particle factory must be based on the geometry, so the geometry of the particle factory needs to be built. The geometry types of the particle factories are Box, Cylinder and Polygon respectively. In this paper, a polygon geometry is built. The geometry is a square with a length of 800mm, which is above the wave sieve and 230mm from the wave sieve.

### *4.3 Particle factory setting*

Since there are three kinds of ingredients in corn, 3 grain factories are established, which are particle factory of corn kernels, particle factory of broken corn stalks, particle factory of broken corncobs. The types of these three factories are all dynamic. The time for starting particles is 1e-12s, and the total time used to generate particles is 2S. The quality and feed quantity of corn prolapse produced by a granular plant are shown in Table 2.

Table 2 Quality and feed quantity of corn prolapse produced by a granular plant

| Material | The corn kernels | The broken corn stalks | The broken corncobs |
|---|---|---|---|
| feed quantity （kg/s） | 2.2 | 0.51 | 0.3 |
| quality（kg） | 4.4 | 1.02 | 0.6 |

*4.4 Simulation parameter setting*

The simulation time step is 20%, the total simulation time is 10s, and the data output interval is 0.02s. The mesh size is generally set according to the radius of the smallest particle in the simulation model, and the size of the grid is three times the minimum particle radius, so the grid size is set to 3mm in the paper. When using the discrete element software EDEM to simulate and analyze the movement of the corn population during the cleaning process, the simulation area of its motion needs to be set. In order to reduce the calculation amount of EDEM software and speed up the calculation speed, the simulation area is slightly larger than the model area.

## 5 The movement of the corn prolapse in the cleaning device

The discrete element software EDEM was used to simulate the process of corn cleaning. As shown in Figure 5, the movement of corn prolapse at the time of 0.2S, 0.4s, 0.6s and 0.8s was expressed. It can be seen that when the simulation time is 0.2S, the corn prolapse falls on the wave screen first, and then moves back to the louver sieve to screen through the push action of the wave sieve. When the simulation time is 0.4s, no new corn prolapse appears, and the quality of corn prolapse in the cleaning device decreases. When the simulation time is 0.6s, the quality of the corn prolapse on the wave screen and the fish scale sieve is obviously reduced. Corn prolapse is concentrated at the junction of the tail sieve and the circular hole sieve. When the simulation time is 0.8s, there is almost no corn prolapse on the tail sieve and the circular hole sieve. At this time, the simulation interface is similar to the interface of the simulation time for the 0.6s moment, which shows that the cleaning process is basically completed .

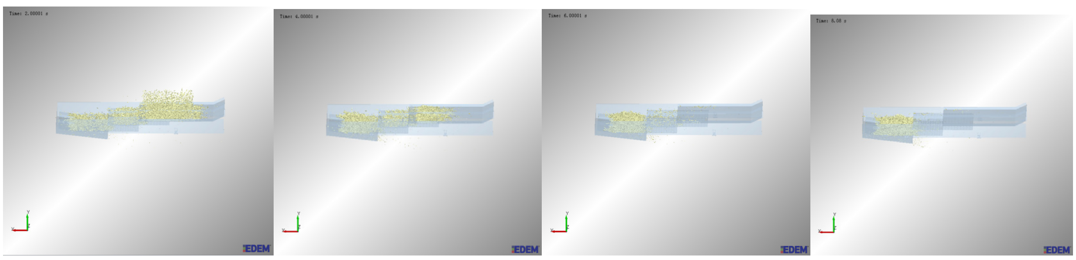


Figure 5 The movement of the corn prolapse in the cleaning device

The change of the speed of the corn prolapse during the cleaning process is observed as shown in Figure 6. This is the velocity cloud chart of the corn prolapse when the simulation is carried out at 2S and 4S. It can be seen that the speed of corn prolapse is larger in louver sieve and circular hole sieve than that on wave sieve and tail sieve. It is known that the impact of corn prolapse on louver sieve and circular hole sieve is large, and the impact on wave sieve and tail sieve is small.

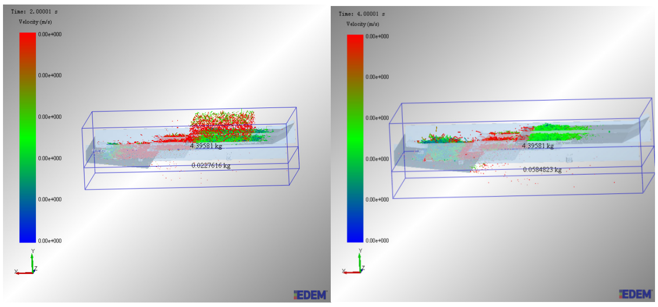


Figure 6 The speed cloud chart of cleaning process

In order to track the trajectories of corn prolapse, red, black and blue colors are set for corn kernels, broken corncobs and broken corn stalks. A particle is randomly selected from the group of corn kernels, the group of broken corn stalks and the group of broken corncobs. The trajectories are shown in Figure 7. From the red curve in the picture, we can see that most of the corn kernels are passed through the louver sieve into the circular hole sieve, and are finally collected through the circular hole sieve. From the blue curve and the black curve, most of the broken corn stalks and broken corncobs move backward through louver sieve, and finally fall into the circular hole sieve, but their size is larger than the size of the circular hole sieve, and finally they are left on the sieve surface.

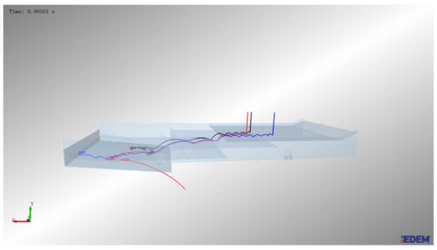


Figure 7 Trajectories of various components in corn prolapse

## 6 Conclusions

(1)From the movement condition of the corn prolapse in the cleaning device, it is known that the wave sieve and the louver sieve can push the corn prolapse out back, so the structure of the two sieves should be designed to be beneficial to the backward push out of the corn prolapse.

(2)It can be seen from the speed cloud chart of cleaning process of the corn prolapse during the cleaning process that the speed of the corn prolapse on the louver sieve and the circular hole sieve is large, and the movement speed on the wave sieve and the tail sieve is small.

(3)The movement Trajectories of the corn prolapse show that most of the surplus is left at the junction of the circular hole sieve and the tail sieve, and the corn kernels are penetrated through the circular hole sieve into the container of corn kernels.

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