Simulation Analysis of Soil Covering Process

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Abstract. Soil mulching device is an important part of precision seeder, its structural parameters and performance will directly affect the uniformity of seed distribution and the thickness of soil, and ultimately affect crop yield. Using the EDEM tool based on the discrete element method, the optimized structure of the earth covering device was simulated and analyzed. The soil-slot test was used as a comparative test of the soil simulation experiment. The comparison between the results of the simulation test and the earth covering process test confirmed the applicability of the discrete element method to the earth covering process, which provides a new way for the research and design of the earth covering device and the earth covering process.

Keywords: Earth cover, Discrete element method, Seed displacement

1. Introduction

The discrete element method is to decompose the granular material into relatively independent units, and each unit has the same properties as the original material, the interaction and movement of each unit can be simulated and studied through the setting of relevant parameters, and the distribution of each unit and relevant data can be obtained intuitively. Based on the basic principle and characteristics of the discrete element tool, the discrete element method can be applied to the study of the process of covering soil. Using its chart analysis module to analyze the obtained data, providing a technical reference for the structural optimization and performance improvement of mechanical equipment.

2. The Establishment of Simulation Model of Soil-covering Process

First of all, we need to set up the Creator of the pre-processing module of the EDEM discrete element tool, including inputting the relevant characteristic values of related materials and the interaction parameters between material units, establishing an independent material unit model, importing three-dimensional geometric objects through the indirect port of the software, and setting the size and position parameters of geometric objects and materials, etc.

2.1. Establish a soil trough model of the soil covering process.

In order to fully simulate the test conditions of the actual soil covering process, we need to establish a soil trough model in the EDEM discrete element software. Considering the width dimension of the soil tank, it is necessary to contain the earth cover model, and the thickness of the soil particles should be easy to
observe the final simulation effect and other factors. So we have to establish a soil trough test bench with length, width and height of 0.7 m × 0.5 m × 0.5 m. It was found that the material will jump out of the soil trough during the process of covering soil.\[1-3\] In order to avoid the loss of relevant particle data and the distortion of simulation effect, the soil trough test-bed was set up to be a physical.

2.2. Establishment of plant for soil monomer and its material generation.
The model of soil monomer is spherical, and the radius base is 0.03 m, that is to say, the radius of the generated soil monomer particles will change within a certain multiple of 0.03 m; because of the cohesion between the soil monomers, the contact mode between the soil monomers is set as adhesive contact type.

A box geometry is added as a static material generation plant. Its type is virtual geometry. The length, width and height dimensions of the box are 0.7m, 0.5m and 0.07m. Namely, at the beginning of the simulation, 0.07m-thick soil particles will be generated statically, and the generated material monomer radius will vary from 0.2m × 0.03m to 1.2m × 0.03m. The total number of material monomers is 600,000. Dynamic materials are set. In order to integrate the dynamic soil monomer into the pore of static soil monomer as soon as possible, the loose degree of simulation soil model is closer to the actual soil condition, and the number of dynamic material monomer is 50,000.

2.3. Establishment of corn granule model.
In order to track the displacement of the corn granules, a corn granule model is set and the relevant parameters are entered. According to the data measured in advance, corn grains are set to be spherical and the radius of corn grains is set to be 1.5 mm; three virtual planes are set above the per planned soil layer with an interval of 100 mm, which are used to generate corn grains dynamically.\[4-6\] Each of the virtual planes generates a single corn unit, giving each corn unit a z-direction speed of -2.3 m / s, which is to simulate precision sowing. The process of seeding before the seeder is covered with soil. Each virtual plane has a radius of 1.5 mm and a semicircle with 30 sides.

2.4. Introduce the geometric model of the soil cover.
The soil cover model of the optimal structure established in Solid Works software in advance and imported obtained from the soil tank test data into the EDEM discrete element tool.\[7-8\] The soil cover is started in the 0.36s of the simulation test, and the travel speed of the soil cover along the X direction is set to -1.2m/s.

The main physical parameters used in the simulation are shown in Table 1. The collision recovery coefficient is expressed by E, the dynamic friction coefficient is expressed by F, and the static friction coefficient is expressed by μ.

| Physical Attributes | Parameter Value | Physical Attributes | Parameter Value |
|---------------------|-----------------|---------------------|-----------------|
| E Soil-maize.       | 0.16            | F Soil-Soil         | 0.21            |
| MSOIL-CORN          | 0.22            | E Corn-Corn         | 0.18            |
| F Soil-maize.       | 0.09            | μ Corn-Corn         | 0.20            |
| E Soil-mulch.       | 0.21            | F Corn-mulch        | 0.08            |
| μ SOIL-COVERER       | 0.38            | E Earth Coverer-Corn| 0.62            |
| F Soil-mulch.       | 0.30            | F Corn mulch.       | 0.09            |
| E Soil-Soil         | 0.10            | μ-Corn mulch        | 0.46            |
| MSOIL-SOIL          | 0.35            |                     |                 |

3. The Process of Simulation
Set the time step of simulation calculation to be 9.85e-6, the simulation time to be 2 s, and the number of processors is 4. The simulation process and soil covering effect are shown in Figure 1.
Figure 1. Simulated picture of soil covering device

From the effect map of covering soil, it can be seen that small soil monomers are mostly located at the height of seeds after the completion of covering soil, while medium and large soil monomers cover the surface of small soil monomers, which shows that after structural optimization, the covering device can first complete wet soil that covering with small front-end disks, and then complete surface that covering with large back-end disks. Basically, the results reached the desired effect.

4. Data Analysis of the Simulation Process.
In order to obtain the coordinates and displacement values of corn monomer, the coordinate values of corn monomer generated by the EDEM tool solving module were exported to an Excel table, and the average displacement values were calculated. The X coordinates of some specific time points of each corn monomer were shown in Table 2.

| Time (s) | Coordinates 1 (m) | Coordinates 2 (m) | Coordinates 3 (m) |
|----------|-------------------|-------------------|-------------------|
| 0.33     | 0.09              | 0.001             | -0.107            |
| 1        | 0.087             | 0.008             | -0.112            |
| 1.2      | 0.086             | 0.008             | -0.111            |
| 1.4      | 0.086             | 0.006             | -0.111            |
| Displacement | 0.003         | 0.005             | 0.006             |

Average displacement 0.005

As can be seen from Figure 2 and Table 2, the three corn grains all have a certain displacement along the moving direction of the soil mulch, the maximum displacement is 0.003 m, 0.005 m and 0.006 m, respectively, and the mean displacement is 0.005 m, while the maximum displacement of the seed measured by the soil tank test is 0.006 m, the minimum displacement is 0.003 m, and the mean displacement is 0.004 m. The simulation results are consistent with the experimental results to a certain...
extent, which confirms the applicability of the discrete element method to the problems related to the soil covering process.

5. Conclusion
In this paper, the physical parameters needed for simulation are obtained by referring to previous scholars’ the methods of physical parameters determination, the virtual soil tank model and material monomer needed for simulation are established, the three-dimensional model of soil covering device is imported through software interface, and the motion and time parameters are reasonably set according to the connection relationship of each process. By comparing the results of simulation test and soil tank test, the applicability of discrete element method for soil covering process is confirmed, which provides a new way for the research and design of soil covering device and soil covering process.

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