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Analysis of garlics lateral conveying performance based on EDEM

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Analysis of garlics lateral conveying performance based on EDEM

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Abstract. This article studied the effect of different conveyor belt speeds on garlics transportation in the process of garlics harvesting and lateral conveying. The lateral conveying process of garlics is simulated by EDEM, and the optimal transportation speed interval is obtained by simulating different transportation speeds. The simulation results show that the conveying speed range of conveyor belt is 2.46-3.46 m /s when the plant spacing of garlics is 0.1 m, the row spacing is 0.12 m, and the 16 harvesting units of garlics combine harvester harvest at the speed of 2 m/s at the same time, which can effectively avoid the problem of garlics accumulation on the lateral conveyor belt when the conveying speed is too slow, and garlics leakage and garlics secondary damage problems when the delivery speed is too fast. The research can provide some theoretical reference for the design of garlics transversal conveyer and the selection of conveying speed.

1. Introduction

As garlic industry is one of China's traditional characteristic industries, Chinese garlic total production and export volume lie front rank in the world each year [1]. However, at present, garlic harvesting in most areas of China still relies on human and has a low level of mechanization. The garlic combine harvester[2] which can be used for digging, soil cleaning, root cutting, stem cutting or bundling is still in the designed stage and has not been popularized and applied in production practice. In addition, there is little research on garlic collection. Now most garlic combine harvesters use modular harvesting units[3], and each harvesting unit harvests its corresponding row of garlic. When multiple harvesting units harvest at the same time, there are strict requirements for garlic transportation, because when the transportation speed is too slow, it is easy to accumulate garlic, and when the transportation speed is too fast, it is easy to cause secondary injury and leakage of garlic. Therefore, it is of great significance to study the conveying speed of horizontal conveyor belt in garlic collection.

Discrete element method[4] is first proposed by Cundall in the 1970s, which is the initially numerical method to simulate the mechanical process of rock blocks and particle groups in the field of geotechnical engineering. At present, discrete element method has been successfully applied in many granular material analysis fields, and discrete element software such as EDEM[5] has been developed successively. By summarizing the application status of discrete element method in agricultural engineering, Li Lei[6] prospected its application in agricultural engineering in view of the limitations of discrete element method. Compared to traditional methods, Shi Jun[7] found that the discrete element method had a greater advantage in studying the problem of conveying materials by conveyor belt. In the garlic collection link, the garlic on the horizontal conveyor belt is a relatively complex granular material system, which can be studied by using the discrete element method.

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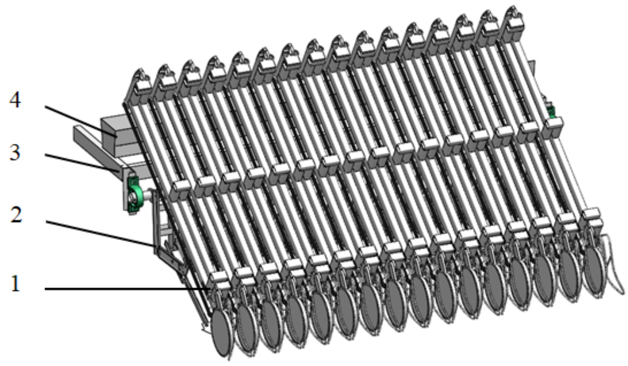
In this paper, the movement of garlics on the lateral conveyor belt was simulated based on EDEM. The distribution and movement of garlics during transportation were analyzed. The number and speed of garlics flowing through the grid box was record. The effect of different transport speeds on the lateral conveying of garlic was studied. At last, the optimal conveying speed interval was also obtained. The research results in the paper can provide some theoretical reference for the design of the lateral conveying device and the selection of conveying speed in the garlic collecting process.

2. Simulation model Construction and parameter determination

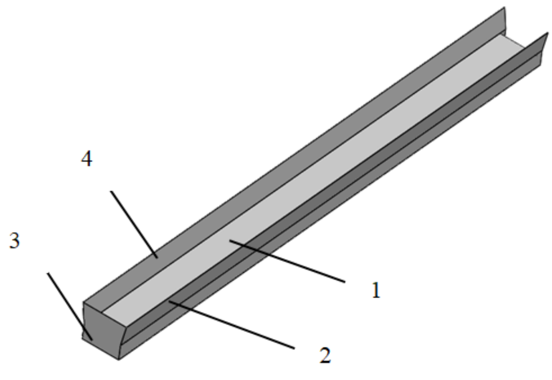
Garlic multi-unit harvesting device (Fig. 1) mainly consists of the soil ripping unit, garlic drawing and conveying unit, body frame and lateral conveyor belt. The soil ripping unit mainly consists of an arrow shaped ripper and an adjusting device for the adjustment of the angle and depth of the shaped ripper. By adjusting the angle and depth of the shaped ripper, the garlic harvester can adapt to garlic digging in different soil and planting depths. The garlic drawing and transporting unit is mainly composed of a synchronous belt conveying device, a garlic-seedling separation device and a root cutting device. The garlic excavated from the breaking soil is transported in the synchronous belt, then the garlic stem separation device and the root cutting device were used to complete the work of garlic-seedling separation and root cutting. Finally, the garlics fall onto the lateral conveying belt, which are transported to the fruit box to complete the garlic collection.



1. Garlic drawing and transporting unit
2. Soil breaking unit
3. Body frame
4. Lateral conveyor belt

Figure 1. Garlic harvesting plant

The lateral conveying belt chose in this paper is a flat belt. The three-dimensional model (Fig. 2) is mainly composed of the conveyor belt, right protective plate, left protective plate and end baffle. The protective plates and baffles are used to prevent garlic from falling off during garlic conveying.



1. Conveyor belt
2. Right protective plate
3. End baffle
4. Left protective plate

Figure 2. Lateral conveyor belt

The three-dimensional model of garlic used in the simulation is filled with multiple balls in the EDEM software. Garlic is filled with 11 small balls (Fig. 3).

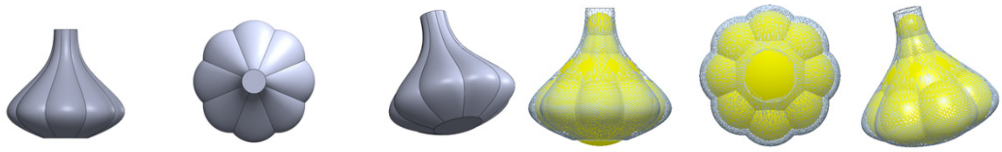
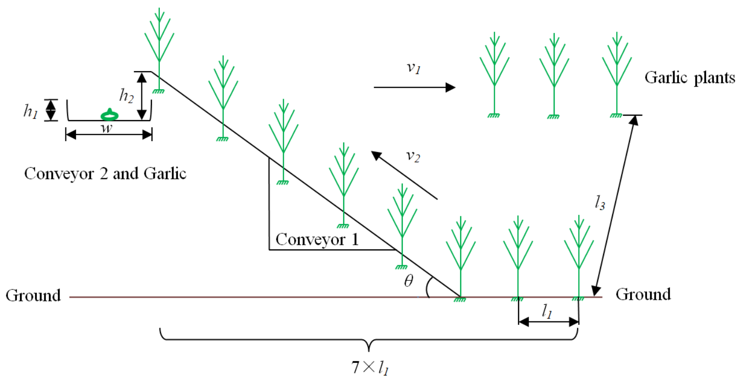


Figure 3. The three-dimensional model of garlic

Table 1. Basic parameters of garlic

Diameter(mm)	Height (mm)	Stem diameter (mm)	Root diameter (mm)	Garlic clove	Weight (g)
*Φ*52	44	*Φ*13	*Φ*25	8	50

Working diagram of single harvesting unit of garlic harvester is shown in the Fig. 4.



l_1. Planting garlic plant spacing
l_3. The row spacing for planting garlic
θ. The Angle between conveyor belt 1 and the ground
v_1. The working speed of garlic harvester
v_2. The transmission speed of the synchronous belt
v_3. Represents the horizontal conveyor belt conveying speed
h_1. The horizontal conveyor belt guard plate height
h_2. The falling height of garlic
w. The width of the horizontal conveyor belt

Figure 4. Working diagram of garlic harvester

3. Simulation and result analysis of garlic transversal transportation

According to the studies of QIN Lixiang[8], WANG Chengjun [9], GOU Bingjiang [10] etc., simulation parameter setting is completed in EDEM software, which were shown in table 2 and table 3.

Table 2. Material physical parameters

physical parameters	Garlic	conveyor belt(rubber)
Poisson's Ratio	0.3	0.49
Shear Modulus(Pa)	2.6×10^6	1×10^6
Density (Kg/m^3)	920	1000

Table 3. Contact parameters between materials

Interaction	Coefficient of static friction	Coefficient of rolling friction	Coefficient of restitution
Garlic-Garlic	0.4	0.05	0.3
Garlic-Rubber	0.5	0.08	0.25

According to the actual garlic planting situation and harvesting speed, the garlic planting plant spacing is 0.1m, the row spacing is 0.12m, the horizontal conveyor belt length is 1.92m, the width is 0.21m, and the guard plate height is 0.12m in this paper. The harvesting speed of the garlic combine harvester which has 16 harvesting units was set to 2m/s as an example, and the global variables were set in EDEM software. If garlics on the lateral conveyor belt is subject only to static friction and is accelerated all the time, it will be transported at maximum speed from one end to the other. According

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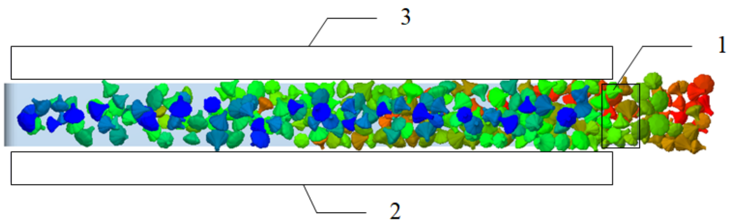
to the above assumptions, the maximum effective conveying speed of the lateral conveyor belt is set to 3.96m/s. Therefore, six groups of conveyor belt speeds are selected for simulation, which are respectively 1.46m/s, 1.96m/s, 2.46m/s, 2.96m/s, 3.46m/s and 3.96m/s.

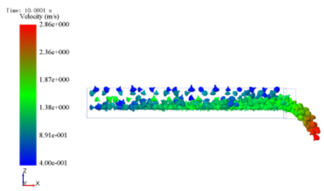
According to the above analysis, 16 garlic particle factories were set up, which had an interval of 0.12m and were located above the lateral garlic conveying device. The time interval for generating garlic particles is set to 0.05s. The Hertz-mindlin (no slip) model was adopted and the total simulation time was set to 10 seconds.

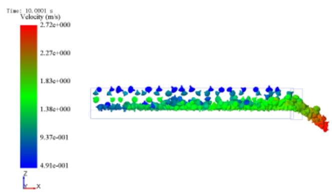
In order to observe the movement state of garlic in the simulation process, grid boxes that can detect the quantity and speed of garlic flowing through them were set at the exit of the lateral conveyor belt and on the left and right sides respectively (Fig 5) . The length, width and height of the grid box at the exit are 0.21m, 0.12m and 0.12m respectively. And the length, width and height of symmetrical grid boxes on both sides of the conveyor belt are 1.92m,0.1m and 0.12m respectively.

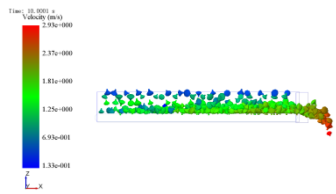


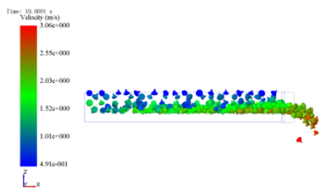
1.The grid box at the exit;2.Right grid box;3.Left grid box
Figure. 5 Grid box distribution diagram

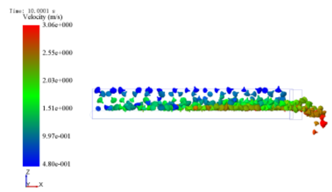
When the lateral conveyor belt speed v_2 is 1.46m/s, 1.96m/s, 2.46m/s, 2.96m/s, 3.46m/s and 3.96m/s respectively, simulation results of garlic movement under steady state are shown in Fig. 6. It can be intuitively observed from the following figure that the accumulation degree of garlic significantly decreases with the increase of conveying speed.


（a） v_2=1.46m/s


（b） v_2=1.96m/s


（c） v_2=2.46m/s


（d） v_2=2.96m/s


（e） v_2=2.96m/s

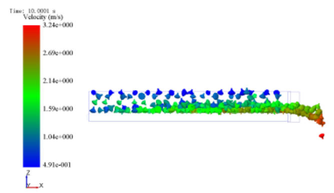

（f） v_2=3.96m/s

Fig. 6 Simulation results of different conveying speeds

When the lateral conveyor belt velocity v_2 is 1.46m/s, 1.96m/s, 2.46m/s, 2.96m/s, 3.46m/s, 3.46m/s and 3.96m/s respectively, the quantity of garlic passing through the grid box at the exit changes with time are shown in Fig. 7.

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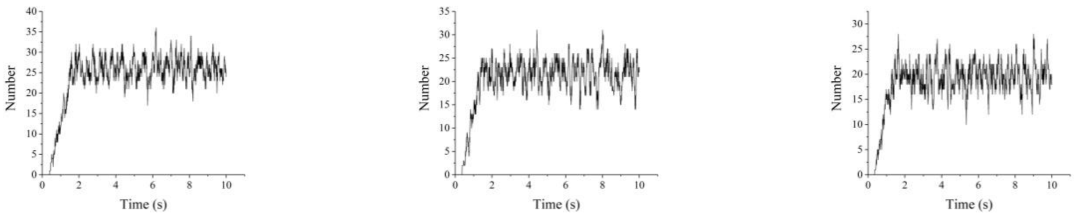
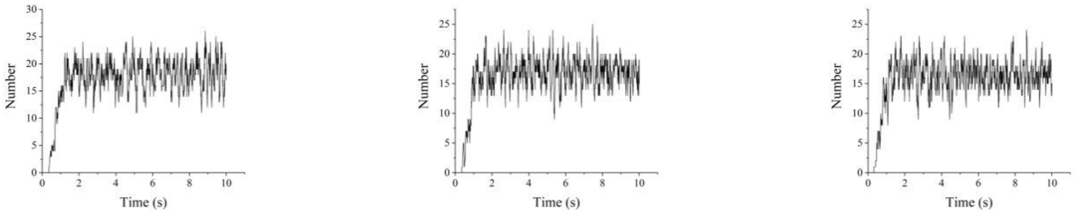


（a） v_2=1.46m/s （b） v_2=1.96m/s （c） v_2=2.46m/s



（d） v_2=2.96m/s （e） v_2=3.46m/s （f） v_2=3.96m/s

Figure. 7 Variation of garlic quantity at different conveying speeds

According to the analysis in the figure above, the lateral conveying of garlic will reach a stable state after about 2 seconds. Under the stable conveying situation, the average of the garlic passing through the grid box at the exit will also be different due to the different conveying speed (Fig. 8).

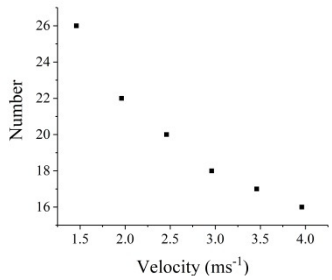


Figure. 8 The relationship between the average quantity of garlic and the conveying speed

When the conveyor belt speed v_2 is 1.46m/s, 1.96m/s, 2.46m/s, 2.96m/s, 3.46m/s, and 3.96m/s respectively, The number of garlic flowing through the grid boxes on the left and right sides of the conveyor belt during the whole simulation process at different conveying speeds is shown in Table 4.

Table 4. The number of garlic passing through the grid boxes on the left and right sides of the conveyor belt at different conveying speeds

v_2(m/s)	1.46	1.96	2.46	2.96	3.46	3.96
Number	0	0	0	0	1	8

When the conveyor belt speed v_2 is 1.46m/s, 1.96m/s and 2.46m/s respectively, the quantity of garlic flowing through the grid boxes on the left and right sides of the conveyor belt is 0. However, as shown in figure 9, the number of garlic in the grid box at the exit is 26, 22 and 20 respectively. When the length, width and height of the conveyor belt are 0.12m, 0.21m and 0.12m respectively, the conveyor belt can hold up to 20 garlic bulbs. When the actual amount of garlic is more than the theoretical amount, excess garlic will falls off with the conveyor belt bobbing up and down during the harvester working. Therefore, the speed of conveyor belt should be greater than 2.46m/s. When the conveyor belt speed is 3.46m/s and 3.96m/s, according to Table 4, it can be found that some garlic will fly out of the grid box at the edge of the conveyor belt. As the conveyor belt speeds up, the number of garlic that will fly out increases also. So the speed of conveyor belt should be less than 3.46m/s.

4. Conclusion

(1) In this paper, discrete element method is used to analyze the garlics collection process. The analysis results show that the discrete element method is feasible to analyze the garlic collection process and can provide a novel and intuitive method for the garlic collection process.

(2) With the increasing of lateral conveyor belt speed, the accumulation of garlic decreased obviously. When the conveying speed is too fast, the garlic on the conveyor belt will fly out of the guard plate, which will cause garlic omission and secondary garlic damage.

(3) When the plant spacing of garlic is 0.1m, the row spacing is 0.12m and the 16 harvesting units of garlic combine harvester are harvested at the speed of 2m/s at the same time, the conveying speed range of the designed conveyor belt is 2.46-3.46m /s, which can effectively avoid the problem of garlics accumulation on the horizontal conveyor belt when the conveying speed is too slow, and garlics leakage and garlics secondary damage problems when the delivery speed is too fast.

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