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DEM Simulation and Analysis of Seeds Supply by the Vibrating Seed Box of Magnetic Cylinder Seeder

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Abstract. Regarding the vibrating seeds box of magnetic cylinder seeder as the research subject and making simulation and analysis for the motion law of seeds which supplied by seed box base on DEM (Discrete Element Method). Researching the mechanism of the seed supply and analyzing the condition of seed supply by the vibration of seed box, when the frequency change from 10Hz to 50Hz and horizontal and vertical amplitude of the seed box are 0.5mm. The results shows that the vibrating frequency has greater influence on the seed supply; seeds can't be supplied when the vibrating frequency less than 10Hz; seed can be supplied best and seeds thickness nearly the cylinder wall is highest when the vibrating frequency equal to 40Hz.

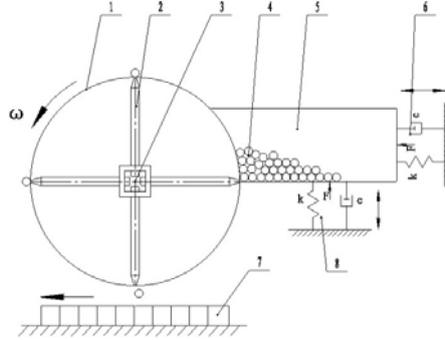
Keywords: Seed Box, Discrete Element Method, Seed Supply, Vibration, Frequency

1 Introduction

Magnetic cylinder seeder can realize the seeding of vegetables, flowers and other small seeds [1]. Its important working assembly is the vibrating seed box which relied on vibrator to supply seeds continuously and stably to the cylinder wall, so the vibration parameters directly affect the property of seeder. There are complex interrelationship collision and friction in the motion of the seeds, which kinematics and dynamics relationship is quite complex, that the traditional continuum mechanics can't analyze the actual movement of seeds [2] [3]. This paper using discrete element method, studying the seed supply situation under the condition of seed box vibration, which provided theoretical basis for the further research of magnetic cylinder seeder.

2 Structure and Working Principle of Magnetic Cylinder Seeder

The structure of magnetic cylinder seeder is shown in fig.1, including cylinder, drive shaft, permanent magnet, seed box, vibration exciter etc.



1.Cylinder 2.Permanent magnet 3.Drive shaft 4.Seed 5.seed box
6. Longitudinal vibration exciter 7.Seed plate 8.Transverse vibration exciter

Fig. 1. The structure of precision magnetic cylinder seeder

Powder coated seeds are placed in half-open vibrating seed box, the open side nearly close to the cylinder wall to prevent seeds falling down; Seeder wheel drives by shaft and makes one way rotating, permanent magnet mounts on the rotating shaft, the magnetic head mounts on the channel of the cylinder and rotates with the cylinder. When the magnetic head turns to the region of seed-filling, the magnetic head adsorb one seed and continue rotates with cylinder, when it turn to the downside of cylinder roller, the seed falls down then one time metering completely.

3 Contact Force Model and Parameter Definition

Contact force model is the core of DEM, the simplify model is always used for calculation during DEM simulation due to much more complex structure particles. The linear viscoelastic contact model has been widely used in the research of the agricultural machinery [4~6], so adopting the linear viscoelastic contact model as the contact force model of seed-seed and seed-seeder elements.

The normal force of liner viscoelastic model [7]:

$$F_n = -k_n \delta_n - c_n \theta_n . \quad (1)$$

F_n : The normal force between two contact particles;

k_n : The normal contact stiffness coefficient, $k_n = \frac{k_1 k_2}{k_1 + k_2}$;

k_1, k_2 : The contact stiffness coefficients of two contact particles;

δ_n : The normal overlap of two contact particles;

C_n : The normal viscous damping coefficients, $C_n = \frac{C_1 C_2}{C_1 + C_2}$;

c_1, c_2 : The normal viscous damping coefficient for two contact particles;

θ_n : The normal contact relative velocity.

Tangential contact force is:

$$F_s(t) = F_s(t - \Delta t) - K_s \theta_s \Delta t - c_s \theta_s . \quad (2)$$

$F_s(t)$: The tangential force between two contact particles at time t;

Δt : The time step;

K_s : The tangential contact stiffness coefficient.

All the parameter needed in the simulation are got from experiment, the details are shown as table 1.

Table 1. Parameter used in DEM analysis

Seed type	Coating rapeseed (iron 20%)
Particle diameter/mm	1.75
Poisson's ratio of particle	0.3
Shear modulus of particle/Pa	4.65×10^8
Particle density/ $\text{Kg} \cdot \text{m}^3$	2.1×10^3
Coefficient of restitution in seed-seed	0.2
Static friction coefficient in seed-seed	0.4
Rolling friction coefficient in seed-seed	0.06
Coefficient of restitution in seed-seeder elements	0.4
Static friction coefficient in seed-seeder elements	0.11
Rolling friction coefficient in seed-seeder elements	0.02

4 Simulation Results

According to the actual experiment, when the seed box amplitude was 0.5mm, metering requirement can be satisfied. During simulation experiment, 0.5mm was selected for the horizontal and vertical amplitude. And simulated the seed supply situation and the movement law of the seeds under the vibration frequency was 10~50Hz.

During the Simulation, cylinder diameter was 100mm, the rotation speed was 20r/min, the size of the seed box was 170 x 60 x 50 mm (length x width x height). 1500 seeds were generated with a normal distribution, which average diameter equal to 3.5mm and the variance was 0.05. Once the filling completed, the seed box started to make a simple harmonic oscillation with the vertical and horizontal direction. There can be clearly shows that influence of frequency for motion of seed supply

according to the simulation result. The duration time of numerical simulation was 3 seconds.

4.1 The Motion Law of Seeds

During the vibration process, seeds always kept the moving condition with friction and collision. When the vibration frequency was low, the seeds moved slowly to the cylinder wall direction, and no longer moved forward when seeds moved to the certain condition. Meanwhile the seeds can only peristalsis with the seed box and unable to be supplied for the seeder, as shown in Fig.2; When the vibration frequency was high, the impetus force that took seeds moved towards to the roller was bigger than the friction force, so seeds moved to the roller direction at a certain speed, and formed a accumulative in the roller wall edge, until seeds movement were steady. At this moment, the seeds would be supplied to seeder stably, as shown in Fig.3.

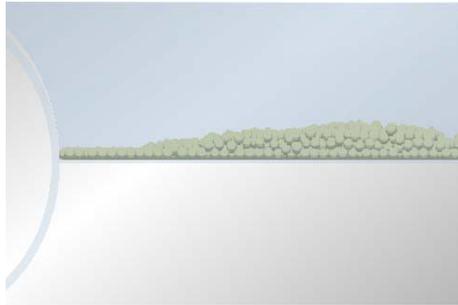


Fig. 2. Seed supply diagram ($f=10\text{Hz}$)

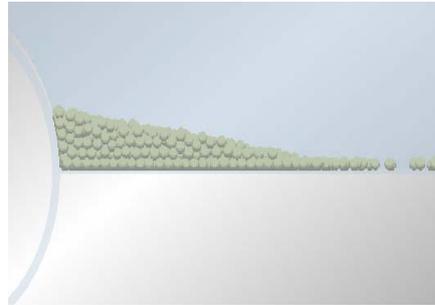
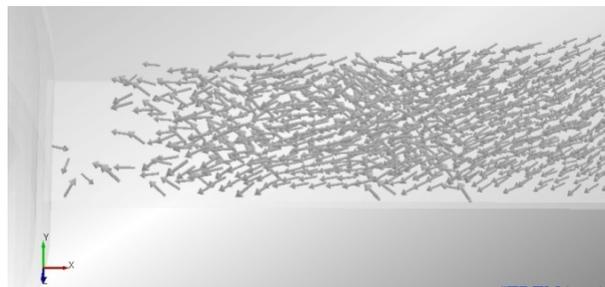


Fig. 3. Seed supply diagram ($f=40\text{Hz}$)

In order to understand the motion of seeds supply situation deeply, this paper simulated the vibration process of seed box when frequency was 50Hz. Fig.4 shown the instantaneous velocity vector chart of the seeds movement when the vibration frequency was 50Hz. It can be seen clearly from the figure that the seeds were influenced by both horizontal and vertical direction amplitude, and moved towards to the cylinder and upward directions.



(a) $t=0.3\text{s}$

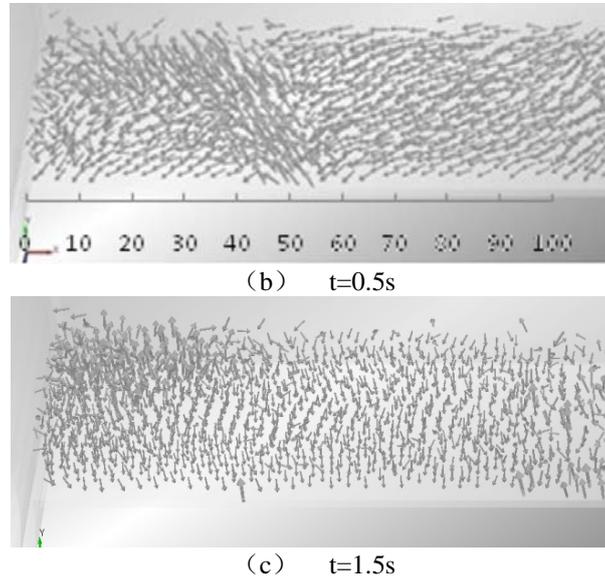


Fig. 4. Instantaneous velocity vector of seeds movement ($f=50\text{HZ}$)

It can be seen from fig.4(a) that after the seed box vibrated 0.3s, the majority seeds moved towards the roller direction by a certain speed; it can be seen from Fig.4(b) that after the seed box vibrated 0.5s, partial seeds contacted and collided with the roller wall, and had a tendency to rebound, enabled these seeds collided once more with the seeds which were moving towards the cylinder direction, there formed a disordered area that the spacing from the roller was 50mm; fig.4(c) showed that, after seed box vibrated 1.5s, the seeds movement basically tends to be stable, with merely creeping motion along with the vibration of the seed box, now seeds in seed box achieved a steady situation for seeds supply.

4.2 Frequency Effect on Seed Supply Situation

Seeds moved towards to the and finally form a certain altitude along the edge of cylinder wall. In this paper, the accumulation height on the cylinder wall edge H was used as the indicator quality of seed supply, as shown in Fig.5.

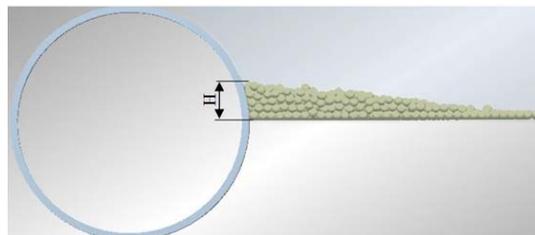


Fig. 5. Seeds accumulation height diagram

The vibration frequency of the seed box was respectively set at 10Hz, 20Hz, 30Hz, 40Hz, 50Hz, simulated the movement process of the seeds along the cylinder wall edge. The simulation result was shown in Fig.6. It can be seen from the figure that the vibration frequency influenced the seeds movement obviously. When the vibration frequency of the seed box was set at 10Hz, the seeds accumulation height was nearly 0, therefore the seed supply were defeated; with the increase of the vibration frequency the accumulation height along the roller wall edge also increased; when the vibration frequency of the seed box was 40 Hz, seeds accumulation height was largest, at this condition seed supply got the best state.

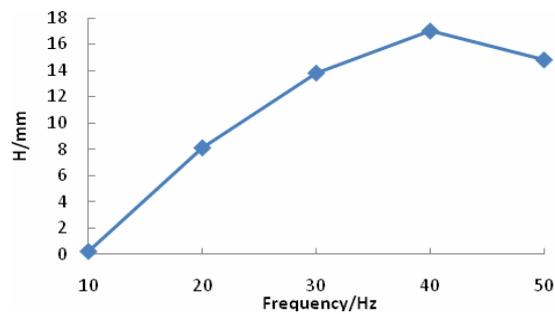


Fig. 6. Seeds accumulation heights under different frequencies

For particular described the condition of seed supply by the vibration of seed box, set a small selection that length \times high \times weight was 10mm \times 15mm \times 30mm along the edge of cylinder wall, as shown in fig.7.

Analyzed the quantity of seeds of this selection in different moment when the vibration frequency of seed box was 10Hz, 20Hz, 30Hz, 40Hz.

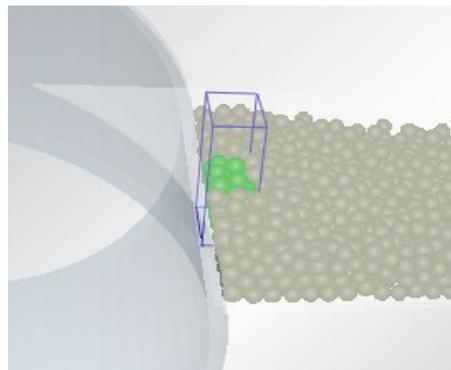


Fig. 7. Small selection along the edge of cylinder wall

As shown in fig.8, seeds entered the small selection along the edge of cylinder wall after seed box vibrating for a period of time; after some time the quantity of seeds in the selection reached a plateau ,and the time turned short with the vibration

frequency increased; after the quantity of seeds reach a plateau, the quantity of seeds has a greatly difference between different frequencies; the larger of the frequency, the more the seeds in the selection, and the better of the condition of seed supply.

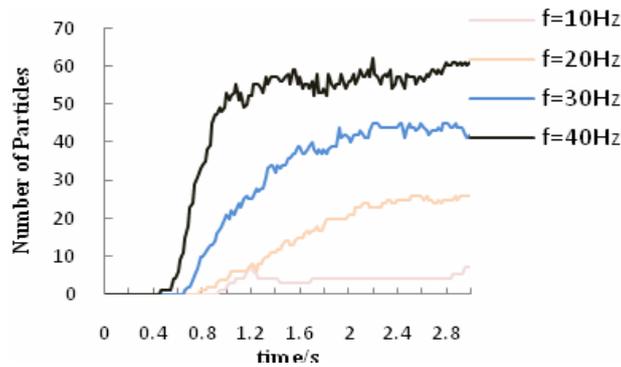


Fig. 8. Seeds total number in small selection under different times

5 Conclusion

Made the vibration seed box of precision magnetic cylinder seeder as research object in this paper, the seed motion law and supply with different frequencies base on DEM were numerical analysis, such conclusions were derived:

1. Using DEM can easily and accurately simulate seeds motion law in the vibration seed box.

2. At the beginning of the vibration, seeds moved toward to cylinder with a certain speed; when seeds contacted with the cylinder, part of them rebounded and collided with the behind seeds which moved to the cylinder wall, then raised a disturbance area within 50mm leave from the cylinder wall; seeds campaign achieved a smooth situation again and only did upward or downward reciprocating movement, then the seed provided in the seed box became to stabilized.

3. Vibration frequency has great influence on seed accumulate height nearly the cylinder roller edge. Seed accumulate height nearly the cylinder roller edge go up with the vibration frequency increased. The seed box can't supply seed when vibration frequency was lower than 10Hz and the best supply seed with the vibration frequency equal to 40Hz.

4. The seeds reached the edge of the cylinder roller wall after a period of vibration; the time required for achieving stability of the seed near the cylinder wall was proportional to the vibration frequency, moreover the more the seeds due to higher frequency, the better for the seed supply situation.

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