The Numerical Simulation Analysis of Pinus sylvestris var. Mongolica seeds Vibration Situation Based on EDEM

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Abstract. The vibrate situation of air-suction type of precision seeder tray have significant influence for seeding effect. So the fundamental principles based on discrete element method was used to simulate the population distribution of Pinus sylvestris var. mongolica seeds in vibration tray by Hertz-Mindlin no sliding contact model of EDEM. Analyzed the influence of vibration frequency, the amplitude of vibration to the seeds population distribution. Divided the simulation region into several tiers along the direction perpendicular to the bottom of the tray, have the distribution of seeds population in different simulation tiers. Study the distribute situation in different parameters got the conclusion that: when frequency was 20Hz, the amplitude of vibration was 5mm, the distribution of seeds population was the most ideal and seeds suction effect was the best; The orientation where 5~15mm from the bottom of the seeds tray was the optimum for seeds suction, can be chosen for efficient seeds suction region.

1. Introduction

Pinus sylvestris var. mongolica as the main afforestation species [1], was being foster by plug seedling, and seed-metering device was the critical component of plug seedling [2]. As the promotion of afforestation in container seedling production, the higher technology requirement was put forward, seeder should conform to the “One Hole One Seed” principle. When use air-suction tray seeder for P. sylvestris var. mongolica, the boundary dimension of seeds can be less considered [3-4], then has higher efficient and lower cost. The theory of flow mechanics of granular materials shows that: when decrease the internal friction factor of granular material, the granular mixtures has more uniform motion and better liquidity. When the internal friction factor of fixed material was constant, we can’t decrease the internal friction factor without change the material status. So, make the seeds which were natural accumulation oscillate, in order to enhance the liquidity of seeds [5].

The vibration of the seeder tray can made the seeds “boiling”, the frictional force of the population seeds was decreased, then the success rate of seeds adsorption was enhanced [6]. So far, the motion state of the population of seeds was studied, but the amount of the seeds which were being simulated was not enough to reflex the motion situation accurately. EDEM, as a kind of multipurpose of discrete element
method simulation software, somebody study the interrelated issues between granular material and mechanical work units [7-8], so the discrete element method were applied to the study of seed-metering device, furrow-ridge-opener device, fertilizer apparatus device, the harvest machinery and so on [9]. This thesis study the vibration situation of *P. sylvestris var. mongolica* seeds population based on EDEM theory, make the numerical simulation analysis under different amplitude and different frequency of the tray, and study the impact that vibrate parameter of the tray has on *P. sylvestris var. mongolica* seeds population spatial form.

2. Simulation Test Design

2.1. *P. sylvestris var. Mongolica* Seeds Contact Model

The contract model such as no sliding contact model, adhesion contact model, moving surface contact model, linear elastic contact model and linear adhesion contact model are the frequently-use contact model in EDEM [10]. The thesis use Hertz-Mindlin no sliding contact model (Fig.1) which was the acquiescent model in EDEM software, as the contract model between the *P. sylvestris var. mongolica* seeds and between the seeds and tray.

\[
\alpha = R_1 + R_2 - |r_1 - r_2| 
\]

Where \( r_1 \) is the center position vector of the spherical particle whose radius was \( R_1 \), and \( r_2 \) is the center position vector of the spherical particle whose radius was \( R_2 \).

The contact area of the two spherical particles was circle and the radius of the circle \( a \) can be calculated as:

\[
a = \sqrt{\alpha R^*} 
\]

While in formula (2), \( R^* \) is the radius of equivalent particle, \( R^* \) can be calculated as formula (3):

\[
\frac{1}{R^*} = \frac{1}{R_1} + \frac{1}{R_2} 
\]
Then the normal contract force between particles \( F_n \) can be calculated as formula (4):

\[
F_n = \frac{4}{3} \alpha^2 E^* \left( R^* \right)^{\frac{3}{2}}
\]  

(4)

Where \( E^* \) is the equivalent elasticity modulus, and so that formula (5):

\[
\frac{1}{E^*} = \frac{1 - \sigma_1^2}{E_1} + \frac{1 - \sigma_2^2}{E_2}
\]

(5)

Where \( E_1 \) —— the elasticity modulus of spherical particle whose radius was \( R_1 \);
\( E_2 \) —— the elasticity modulus of spherical particle whose radius was \( R_2 \);
\( \sigma_1 \) —— the poisson ratio of spherical particle whose radius was \( R_1 \);
\( \sigma_2 \) —— the poisson ratio of spherical particle whose radius was \( R_2 \).

The tangential force between particles \( F_t \) can be calculated as formula (6):

\[
F_t = -S_t \delta
\]

(6)

Where \( \delta \) —— tangential overlap;
\( S_t \) —— tangential rigidity.

While the tangential rigidity \( S_t \) can be calculated as formula (7):

\[
S_t = 8G^* \sqrt{R^* \alpha}
\]

(7)

Where \( G^* \) is the equivalent shear modulus, so that formula (8):

\[
G^* = \frac{2 - \sigma_1^2}{G_1} + \frac{2 - \sigma_2^2}{G_2}
\]

(8)

2.2. Seeds Particles Model

Stochastic selected 100 \textit{P. sylvestris var. mongolica} seeds, measured the three axis dimension of each seed with vernier caliper whose accuracy is 0.01 mm, statistics the three axis dimension of seeds accord with Gaussian distribution, and the average of the three axis dimension of seeds is 4.03mm×2.43mm×2.39mm. When establish the particles model with EDEM, the higher reduction degree of particles model need more base unit, and the simulation time is longer, so ensure the model error while try to reduce the quantity of base unit. Make the model simplification as spheroid according to the three axis dimension of \textit{P. sylvestris var. mongolica} seeds, and the three axis dimension of the model is 4.00mm×2.40mm×2.40mm, the characteristic parameter as follows: the poisson ratio is 0.3, shear modulus 175MPa, density 800kg/m\(^3\), coefficient of restitution 0.3, static friction factor 0.56 and rolling friction factor 0.15; Established the \textit{P. sylvestris var. mongolica} seed model as Fig.2.
The tray of seeds has the length 580mm, width was 70mm and height was 60mm. Origin of the three-dimensional system of coordinate and the center of base tray were coincidence in simulation space, X-Y plane and base tray were parallel, the characteristic parameter as follows: the poisson ratio is 0.28, shear modulus 82GPa, density 7890kg/m³, coefficient of restitution between the tray and seeds is 0.3, static friction factor 0.5 and rolling friction factor 0.1. The tray make simple small amplitude high frequency harmonic vibration along Z-axis direction. Then the vibration made seeds population “boiling” in the tray. Divided the simulation region into several tiers along Z-axis direction in EDEM Post-processing module, while each tier height is 5mm, the Tab I is the coordinate range of each tier. The movement of population under simple harmonic vibration has periodicity, so just need study the situation of population in some period, then all the distribution of population can be conclude.

| Number of simulation tier | 1  | 2  | 3  | ... | 17 | 18 |
|---------------------------|----|----|----|-----|----|----|
| Z-axis coordinate value /mm| -10~5 | -5~0 | 0~5 | ... | 70~75 | 75~80 |

3. Result and Discussion

3.1. The Influence of Frequency with State of Motion

The Fig.3 shows the distribution situation of seeds population when the amplitude A of tray was 5mm, and the vibration frequency f was 15 Hz, 20 Hz, 25 Hz. When the vibration frequency f was 15Hz, the height of seeds population was small and the distribution was concentrate; when the vibration frequency f was 20 Hz, the height of seeds population was smaller, the dispersion degree was promotion and the distribution of seeds population was perfect. As the frequency increase to 25 Hz, the dispersion degree of seeds population was too large, made the density of seeds population decrease then may result in miss sowing, which lead to the loss of accuracy. So the vibration frequency of seeds tray should choose 20 Hz.
3.2. The Influence of Amplitude of Vibration with State of Motion
The chosen vibration frequency was 20Hz, analyse the influence of different amplitude on the distribution of seeds population. Set the amplitude of seed tray A as 4mm, 5mm, 6mm, the Fig.4 was the seeds population distribution when the frequency is equally then amplitude is different: when the frequency is equally, the seeds population height was promotion with the increase of amplitude. When the amplitude was 4mm, the seeds population height and dispersion were not enough, generate the excessive resistance and made seeds suction more difficult; When the amplitude was 5mm, the seeds population height and dispersion more ideal; When the amplitude increase to 6mm, the dispersion of seeds population was too big to suck seeds accurately, the made seeds missing suck, so the amplitude of vibration can be 5mm.

3.3. The Effective Seeds Suction Region
When the vibration frequency $f$ was 20Hz, amplitude A was 5mm, the distribution of seeds population was uniformity. The distribution of seeds in different simulation tier have periodicity (Fig.5), the maximum and minimum of seeds amount have no significant difference. The most seeds distributed at simulation tiers of c: 5-7, and the 6, 7 simulation tier have more seeds than tier 5. So, the effective seeds suction region should choose the 6, 7 simulation tiers, where 5~15mm from the bottom of the seeds tray.
4. Conclusions
When the amplitude of vibration is constant value, the vibration frequency has significant influence to the population distribution, the population distribution was the most ideal when frequency was 20Hz, the seeds suction effect was the best. When the vibration frequency is constant value, the amplitude of vibration have certain influence to the population dispersion, and situation was ideal when the amplitude of vibration was 5mm, when frequency was 20Hz, the amplitude of vibration was 5mm, seeds population dispersion was simulated with EDEM, get the conclusion that: the seeds population space dispersion was uniformity in the parameters, and the orientation where 5~15mm from the bottom of the seeds tray was the optimum for seeds suction.

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