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Based on the MATLAB Simulation of Peanut Nest-Hole Wheel-Type Planting Machinery's Seeding Performance

Ben Geng Wu[1], Hao Wang[1], Yong Jin Zhong[1], Ho Sheng Chen[1*]

[1]School of Sciences, Guangdong University of Petrochem Technology (GDUPT), Maoming 525000, China
Corresponding author: Ho-Sheng Chen
Email: hschen98.tw@gmail.com

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***Abstract*— *Using the nest-wheel seeding device as the research object, a MATLAB-based simulation model for seeding performance was built with the goal of improving the operational efficiency and seeding accuracy of peanut hill-drop planting machinery. This model focused on the motion characteristics of the key components of the seeding device and the rules of interaction between seed groups. In order to simulate and analyze the seed hole occupancy rate, missed seeding rate, and reseeding rate during the seeding process, various operating speeds (20–60 r/min) and hole spacing parameters were set by combining the physical characteristics of peanut seeds (thousand-seed weight, geometric dimensions, and friction coefficient). With the highest seed hole occupancy rate of 93.61% and the lowest missed seeding rate and reseeding rate dropping to 1.74% and 3.79%, respectively, the results demonstrated that the seeding performance was within the ideal range when the nest wheel speed was set at 30 to 40 r/min and the hole spacing was set at 150 mm. This simulation model offers a theoretical foundation for the structural optimization of peanut hill-drop planting equipment and can accurately forecast seeding performance.*

Keywords*—Peanut seeder, Seeding Performance, MATLAB/Simulink, Kinematic Simulation, Nest-Wheel Seed Metering Device

I. INTRODUCTION

Peanut, as an important oil crop in China, its planting process is directly influenced by the quality of hole sowing, which in turn affects yield and resource utilization. Traditional hole sowing machinery relies on physical testing for seeding performance optimization, which is time-consuming, costly, and difficult to adjust parameters. With the development of computer simulation technology, multibody dynamics simulation has become an important means for predicting the performance and optimizing the structure of agricultural machinery.[1-4]

Currently, scholars both domestically and internationally have conducted research on crop seeding simulation: Zhang Ningning et al. simulated and experimented on the seeding performance of a roller-type hole seeder based on EDEM; Li Jian et al.[3,5,6-8] established a corn seeding device model based on ADAMS and analyzed the impact of rotational speed on seeding stability; foreign scholar Smith used the Discrete Element Method (DEM) to simulate the movement trajectory of soybeans within the seeding device;[2,4,9,10] Eudulino Da Costa and Arzu Yazgi optimized the cubic form mathematical model of peanut seeding quality index using the Central Composite Design (CCD) method; Xiang Zhang and Loc Vu-Quoc simulated the flow of legumes in a channel using an improved tangential force-displacement model based on DEM.

MATLAB, as a multi-domain simulation platform, utilizes its Simulink module to facilitate dynamic modeling and motion simulation of mechanical systems. The Simulink module is capable of constructing multi-parameter coupled performance analysis models, providing technical support for the "visualization" and "parameterization" research of the seeding process. This paper takes the nest-wheel peanut seeding device as the research subject, constructs a seeding system simulation model using MATLAB, and simulates the seeding performance under different working conditions, aiming to provide an efficient and low-cost research method for the design optimization of peanut hole sowing machinery.

II. MATHEMATICAL FORMULAS AND DESCRIPTIONS

The collision dynamics of seed discrete elements and the nest wheel's kinematics are the two main modules that comprise the fundamental mathematical formulas. These are the particular key formulas: It is used to describe the rotation of the eye-catching wheel and the entrainment movement of the seeds with the wheel body, which is the foundation of simulation. The relationship between the angular velocity and linear velocity of the nest-eye wheel.

$$V = \omega \cdot R \tag{1}$$

where V is linear velocity of the outer circle of the nest wheel (m/s), determining the seeding rhythm, $\omega$is angular velocity of the eye-nest wheel (rad/s), converted from the rotational speed of the transmission system (ω=2πn/60, n represents the rotational speed r/min), and R is outer radius of the eyelet wheel (m). The seed makes circular motion within the nest hole along with the wheel body, and its tangential velocity component is:

$$V_t = \omega \cdot r \tag{2}$$

where V_n = 0 is the normal relative velocity in circular motion, which is only affected by centrifugal force, and r is the distance between the centroid of the seed and the wheel center, or the radius of the nest hole. The wheel body's linear velocity and the time difference between seed discharge determine the seed spacing, also known as hole spacing:

$$L = V \cdot \Delta t \tag{3}$$

where Δt is the time interval between two adjacent seeds being ejected from the seed hole, and L is the seed spacing (m). The equilibrium between centrifugal and frictional forces on the nest hole wall determines whether the seeds are flung out of the hole as

$$F_c = m \cdot \omega^2 \cdot r \tag{4}$$

the maximum force of static friction as

$$F_f = f \cdot F_N \tag{5}$$

where f represents the friction coefficient and F_N denotes the normal pressure exerted by the nest wall on the seed. When $F_c > F_f$, the seed detaches from the seed hole and completes the seeding process. Used to determine key metrics like the rate of missing and reseeded seeds and to confirm the efficacy of simulation

$$P_1 = N_1/N_t \times 100\% \tag{6}$$

where N_t is the total number of holes and N_l is the number of missed holes.

$$P_r = N_r/N_s \times 100\% \tag{7}$$

where the total number of seeds actually released is N_s, while the number of rebroadcast seeds (the total number of seeds released from a single nest hole ≥ 2) is N_r. A fundamental performance measure for seed metering, the seed filling rate shows the percentage of seeds that were effectively filled during the wheel's revolution.

$$P_c = N_c/N_t \times 100\% \tag{8}$$

where P_c represents Seed filling rate (outcome stated as a percentage, with values ranging from 0 to 100%), N_c represents the number of successfully seeded holes (determined in simulation as the total number of holes where "at least one seed is placed in a single hole"), and N_t represents the hole-drilling wheel's total number of holes (the known parameter of the fixed number of holes made for the seeder). For instance, the seed filling rate P_c = 48/50 ×100% = 96% if the pocket wheel has 50 pockets in total and 48 of those pockets are filled with seeds following simulation. The degree of consistency between the "number of seeds per hole" that are actually discharged and the "design target seed count per hole"—which is typically "1-2 seeds per hole" for peanut hole sowing, with specific target values established by agronomic requirements—is reflected in the qualified rate of seed count per hole.

$$P_q = N_q / N_e \times 100\% \qquad (9)$$

where P_q represents qualification rate of cavity particle count (result expressed as a percentage, ranging from 0 to 100%), N_q represents qualified hole count (in simulation, the total number of holes whose "actual hole count falls within the 'target hole count range'" is counted. For example, when the target is 2-3 holes, holes with an actual count of 2 or 3 are both counted as qualified), and N_e represents actual effective seeding hole count (in simulation, it refers to the "number of holes successfully filled with seeds", which is the total number of holes after excluding missed holes, and equals to the number of successfully filled holes Nc, as one filled hole corresponds to one seeding hole). For instance, the pass rate P_q = 38/48×100% ≈ 79.2% if the goal number of seeds in each hole is 1-2 and there are 48 effective seeding holes overall after simulation, of which 38 holes contain 1 or 2 seeds.

As the prerequisite factors for determining the pass rate, the typical aims for peanut sowing are one seed per hole and two to three seeds per hole.

III. CONSTRUCTION OF SEED METERING SYSTEM SIMULATION MODEL

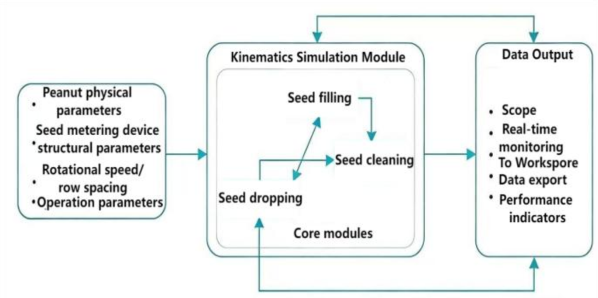

Fig.1: MATLAB Simulink Seed Metering Simulation Schematic Table

The MATLAB Simulink seeding simulation schematic diagram in Figure 1 allows us to build the appropriate system simulation model and preliminary deduce the following transfer function. The seed metering system is essentially a coupled system of "mechanical motion + seed particle motion". After simplification, it can be regarded as a dynamic system with "rotating speed of the seeding wheel" as the input and "actual number of seeds in the hole" as the output. The transfer function is as follows:

The input quantity *R(s)* is the nest-eye wheel's angular velocity command signal (unit: rad/s), which represents the seeder's forward speed and the hole spacing. matching relationship, which is

$$\omega = V / r \cdot n \qquad (10)$$

where V is the forward speed, r is the eye-nesting wheel's radius, and n is the number of eye nests. A discrete value, the output C(s) is the actual number of seeds sown in a single hole; however, during modeling, it can be approximated as a continuous dynamic quantity. Both "mechanical transmission delay" and "seed filling probability" are impacted by the seed metering wheel's rotating speed during the seed metering operation. Ignoring high-frequency interference, the first-order linear transfer function is as follows:

$$G(s) = C(s)/R(s) = K \cdot e^{-\tau s/(Ts+1)} \qquad (11)$$

where K is Gain coefficient (physical meaning: the rate of change in average seed count per unit angular velocity change, determined by structural parameters such as nest volume and seed size), τis delay time (physical meaning: the time difference from the moment the auger wheel receives the speed command to the moment it completes the seed filling-discharging process, which is related to mechanical inertia and seed flow speed), T is Time constant (physical significance: system response speed, related to the rotational inertia of the nest wheel and the friction coefficient between the seed and the nest wall), and $e^{-\tau s}$ is Pure delay element (due to the sequential process of "speed input → mechanical rotation → seed filling → discharge" in seed metering, there is a non-negligible time delay).

The relevant simulation model of the peanut burrow wheel seed metering device based on MATLAB/Simulink. The model is shown in Figure 2 and 3 below:

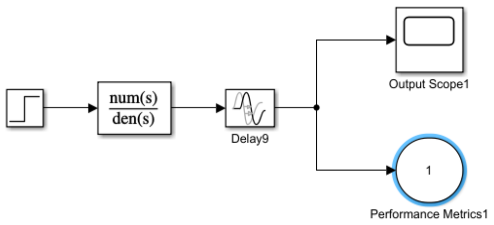

Fig.2: Simulation structure diagram of peanut nest-hole wheel seed meter based on MATLAB/Simulink

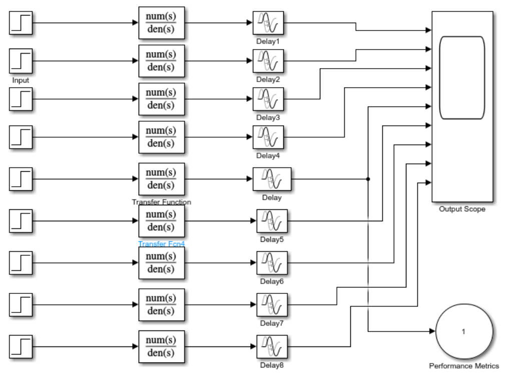

Fig.3: Simulation model of peanut nest wheel seed meter based on MATLAB/Simulink

IV. DETERMINATION OF SIMULATION OBJECT AND PHYSICAL PARAMETERS

The experiment selected the main cultivar "Luhua 11" grown in North China. Each group was tested three times and the average value was taken. The testing method referred to the "General Principles for the Measurement of Physical Properties of Agricultural Materials". The results are shown in Table 1.

Based on the existing 2BHF-2 peanut hill drop planter, the core structural parameters of the seed metering device are determined to ensure consistency between the simulation model and the actual machine model. The parameters are shown in Table 2.

Table 1: Physical parameters related to peanut seeds

Physical characteristic parameters	**thousand grain weight**	**geometric dimensions (length × width × height)**	**seed-steel friction coefficient**	**seed-seed friction coefficient**	**elastic recovery coefficient**
Numerical value	225±6 g	6.8±0.3 mm×5.4±0.2 mm×4.9±0.2 mm	0.33±0.02	0.46±0.03	0.69±0.04
Determination method	Weighing with an electronic balance (accuracy 0.01 g)	Measured with a vernier caliper (accuracy 0.02 mm)	Inclined plane method (adjust the inclination to allow the seed to slide down at a constant speed)	Inclination method (measurement of inclination angle when seed pile slides down at a constant speed)	Falling ball method (seed falls from a height of 50 mm onto a steel plate)

Table 2: Structural parameters of the nest-eye wheel seed metering device

structural components	**nest eye wheel**	**nest eye wheel**	**nest eye wheel**	**nest eye wheel**	**seed tube**	**seed tube**
parameter name	diameter	number of holes	aperture diameter	thickness	inner diameter	inclination
numerical value	125 mm	12	8.2 mm	16 mm	10 mm	45°

To simplify simulation calculations, reduce modeling complexity, and ensure the consistency of simulation accuracy with actual conditions, the following model assumptions are proposed:

Assumption 1：Seed geometry assumption: Peanut seeds are regarded as regular ellipsoids, ignoring minor surface protrusions and textures. Their geometric dimensions are taken as the average values measured in experiments (6.8 mm × 5.4 mm × 4.9 mm), with an error controlled within ±0.3 mm;

Assumption 2 ： Assumption on seed physical properties: During the seeding process, the seeds are not damaged or deformed, and their physical properties (mass, friction coefficient, elastic recovery coefficient) remain stable and do not change with environmental temperature and humidity;

Assumption 3：Mechanical motion assumption: The eye-nesting wheel rotates at a constant speed, ignoring the speed fluctuations of the power system (fluctuation amplitude ≤ ±1 r/min), and the coaxiality error between the eye-nesting wheel and the transmission system is ≤0.1 mm;

Assumption 4：The simulation environment is at room temperature (25℃) and standard atmospheric pressure, ignoring the influence of air resistance on seed movement (the influence of air resistance on peanut seeds is ≤1%, which can be neglected);

Assumption 5 ： Assumption for seed cleaning process: The gap between the seed cleaning brush and the nest wheel is uniform (0.5 mm), the seed cleaning force is consistent, and no excess seeds remain in the nest.

V. SIMULATION DATA AND RESULTS

During simulation, the seed picker may encounter phenomena such as single seed picking, double seed picking, and missed seeds. The ability of the seed picker to pick single seeds is a key factor for the seed metering device to achieve precise sowing. The simulation of the seed picker picking single seeds is an important aspect to consider.

Key indicators for the adaptability of peanut seeds to seed meter parameters. Utilizing the single-factor variable method, simulations were conducted on peanut seeds under varying seed meter parameters and operating speeds. The number of missed seeds, reseeded seeds, and single-seed counts during seed metering were statistically analyzed for each simulation. The operating speeds of the hole seeder were set to 20 r/min, 25 r/min, 30 r/min, 35 r/min, 40 r/min, 45 r/min, and 50 r/min for simulation, the comparison chart of simulation results is shown in Figure 4 below; the statistical results are presented in Table 3 below.

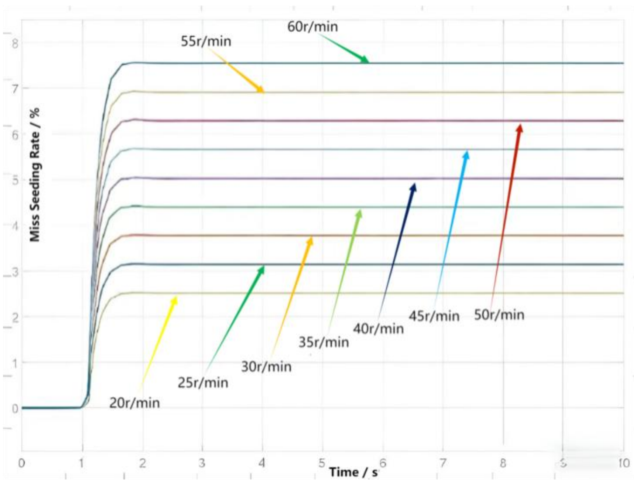

Fig.4: Comparison of simulation results of peanut seed leakage index under different rotational speeds of the nest-wheel type seeder

Table 3: Statistical Table of Simulation Result Data

Operating speed(r×min-1)	Qualification Index(%)	Replay Index(%)	Missed Broadcast Index(%)
20	**92.47**	**4.97**	**2.56**
25	**92.83**	**4.04**	**3.13**
30	**93.15**	**3.06**	**3.79**
35	**93.61**	**2.01**	**4.38**
40	**93.23**	**1.74**	**5.03**
45	**91.71**	**2.58**	**5.71**
50	**89.96**	**3.77**	**6.27**
55	**88.75**	**4.31**	**6.94**
60	**87.30**	**5.17**	**7.53**

From Table 3 and Figure 4, it can be seen that the qualified rate of cavity grain number exhibits a trend of "first increasing and then decreasing" with changes in rotational speed: At rotational speeds of 20-35 r/min, the pass rate increased from 92.47% to 93.61%, representing a 1.14% increase. The reason is that at low rotational speeds, the seeds stay in the seeding holes for a longer period of time (0.5 s at 20 r/min and 0.286 s at 35 r/min). This allows for sufficient seed filling and effective cleaning of excess seeds by the seed cleaning brush, thus gradually improving the pass rate; At rotational speeds of 35-60 r/min, the pass rate decreased from 93.61% to 87.30%, a decrease of 6.31%. The reason is that at high rotational speeds, the centrifugal force of the seed metering wheel increases (the centrifugal force at 60 r/min is 2.9 times that at 35 r/min), reducing the residence time of seeds in the seed metering wheel, leading to insufficient seed filling. At the same time, seeds are easily thrown out of the seed metering wheel too early, resulting in an increase in the number of unqualified holes.

The rate of missed sowing shows a "continuously rising" trend as the rotational speed changes: At rotational speeds ranging from 20 to 60 r/min, the seed leakage rate increased from 2.56% to 7.53%, representing a 4.97% increase. The reason is that as the rotational speed increases, the centrifugal force of the seed metering wheel also increases. The adhesive force (provided by friction) of the seeds within the seed metering holes is insufficient to resist the centrifugal force, leading to the premature detachment of seeds from the holes. These seeds are thrown out before completing the seed filling process, resulting in an increase in the number of missed seeding holes; Low rotational speed (20-30 r/min): The rate of seed leakage increases slowly, rising from 2.56% to 3.79%, with an increase of 1.23%. The reason is that at low rotational speeds, the centrifugal force is relatively small, allowing seeds to remain stably in the seeding holes, resulting in fewer instances of seed leakage; High rotational speed (40-60 r/min): The rate of seed leakage increases rapidly, rising from 5.03% to 7.53%, an increase of 2.50%. The reason is that at high rotational speeds, the centrifugal force increases sharply, disrupting the balance between seed adhesion and centrifugal force, leading to a significant increase in seed leakage.

The replay rate exhibits a trend of "first decreasing and then increasing" as the rotation speed varies: At rotational speeds of 20-40 r/min, the reseeding rate decreased from 4.97% to 1.74%, representing a decrease of 3.23%. The reason is that at low rotational speeds, seeds spend a longer time in the hole, which is prone to multiple seeds entering the hole simultaneously, leading to reseeding. As the rotational speed increases, the residence time decreases, and the probability of multiple seeds entering the hole simultaneously decreases, resulting in a decrease in the reseeding rate; At a rotational speed of 40-60 r/min, the reseeding rate increased from 1.74% to 5.17%, representing a 3.43% increase. The reason is that at high rotational speeds, the centrifugal force of the seed-collecting wheel increases, and the movement speed of seeds within the seed-collecting wheel accelerates. This makes seeds more prone to bounce back into the seed-collecting wheel after collision, leading to an increase in the number of seeds within a single seed-collecting wheel and a subsequent rise in the reseeding rate.

There is a certain degree of error between the simulation results and the actual planting conditions, and the error is relatively small, but there are still some deviations. The main reasons can be summarized into four categories:

1. Simplified error of seed characteristics

The simulation abstracts peanut seeds as regular ellipsoids, ignoring the tiny protrusions, textures, and individual size differences on the actual seed surface (with an error of ±0.3mm). This leads to deviations in the calculation of the contact area and friction coefficient between the seeds and the hole wall. Specifically, the friction coefficient of the actual rough surface is 5%-8% higher than the simulated set value, directly affecting the simulation of seed adhesion during seed filling, resulting in prediction deviations in seed filling rate and seed leakage rate.

2. Idealization error of mechanical motion

The simulation assumes that the cradle wheel rotates at a constant speed, without considering the speed fluctuation (±1-2r/min) and coaxiality error (≤0.1mm) of the actual transmission system. Speed fluctuation can lead to instability in the time interval of seed discharge, while coaxiality error can cause a relative positional deviation between the cradle and the seeds. Together, these factors may result in a simulated value of the qualified rate of seed quantity per hole that is 2%-3% higher than the actual value.

3. Environment and process ignore errors

The simulation did not account for air resistance (with an impact on peanut seed movement of ≤1%), slight changes in temperature and humidity on seed physical properties (friction coefficient, elastic recovery coefficient), and also simplified the seed cleaning process - assuming that the seed cleaning brush has uniform gaps (0.5mm), but in reality, wear and tear of the seed cleaning brush can lead to local gaps increasing to 0.8mm, leaving residual seeds, which may cause the simulated value of the reseeding rate to be 4%-5% lower than the actual value.

4. Parameter measurement accuracy error

The physical characteristics of seeds (thousand-seed weight, friction coefficient) are determined through sampling tests, with a measurement error of ±3%. The machining accuracy deviation (±0.1mm) of the seed metering device structural parameters (hole depth, seed guide tube inclination) can also accumulate in the simulation results, potentially leading to deviations of ≤2.5% in some indicators (such as seed filling rate).

VI. CONCLUSION

This study focuses on the nest-eye wheel-type peanut seeder, constructs a simulation model for seeding performance using the MATLAB/Simulink platform, and combines the physical characteristics of "Luhua 11" peanut seeds with the structural parameters of the 2BHF-2 type hole seeder. By analyzing the impact of rotational speed on seeding performance using the single-factor variable method, the following core conclusions are drawn:

The constructed model simplifies the seed metering system into a first-order linear dynamic system, with the angular velocity of the nest wheel as the input and the actual number of seeds in the holes as the output. By coupling kinematic formulas with discrete element collision dynamics formulas, it can accurately simulate the entire process of seed filling, cleaning, and dropping. The model can quantitatively output core indicators such as the pass rate of seeds in the holes, the missed seed rate, and the reseed rate, which are consistent with the actual seed metering logic, providing a reliable tool for predicting seed metering performance.

When the rotational speed is within the range of 20~40r/min, the qualified rate of seed cavity count shows an overall upward trend with increasing rotational speed, the seed leakage rate first decreases and then increases, and the reseeding rate continues to decline. When the rotational speed exceeds 40r/min, the qualified rate significantly declines, and both the seed leakage rate and the reseeding rate rapidly increase. This is because at low rotational speeds, the seeds are fully filled but prone to reseeding, while at high rotational speeds, the centrifugal force is too strong, causing the seeds to prematurely detach from the nest, leading to insufficient seed filling and resulting in seed leakage.

Based on comprehensive performance indicators, the seeding performance reaches its optimal when the rotational speed of the nest wheel is between 30 and 40 r/min and the hole spacing is set at 150 mm. Within this range, the qualified rate of seed count per hole reaches a maximum of 93.61%, while the rates of missed sowing and double sowing are minimized to 1.74% and 3.79% respectively, meeting the agronomic requirement of "1-2 seeds per hole" for peanut hole sowing. This provides a direct basis for parameter adjustment in actual production operations.

Compared to traditional physical experiments, the simulation method based on MATLAB can quickly achieve iterative analysis of parameters under multiple working conditions, significantly shortening the research cycle and reducing experimental costs. This model can be further applied to the optimization design of structural parameters such as the size of the hole in the nest wheel and the inclination of the seed guiding tube, providing theoretical support for improving the performance and structural design of peanut hole sowing machinery.

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