Design and Analysis of Self-propelled Vegetable Seeder

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Abstract. The design of this paper is to draw lessons from and optimize the advanced design at home and abroad, and design a vegetable seeder that can better adapt to the actual complex sowing situation in China. This design uses air-suction metering device, which can accurately sow seeds and improve the production efficiency. This design improves the overall structure of the seeder to adapt to different sizes and rugged and complex land conditions, whether complex hilly or flat terrain, no matter how well the soil can adapt. The sowing amount, plant spacing and row spacing can be adjusted in a wide range to meet the different needs of sowing. With a small change in the structure, the actual production needs can be met. Keywords: Vegetable seeder; Seeding device; precision seeding

Keywords: Self-propelled, Vegetable Seeder, Design

1. Introduction
With the development of the times, vegetable cultivation has entered a new period. Unlike previous planting, people now pay more attention to the quality of vegetables. This means that more investment is needed in vegetable cultivation, and more advanced planting techniques and tools are needed to strengthen the management of crop growth period [1~3]. Vegetable production in the United States, Korea, Germany, Japan, Italy, France and other countries has a high degree of mechanization. At present, advanced vegetable seeding equipment has been able to complete ditching, sowing, covering soil and other tasks, and can form joint operation machines with other large-scale equipment. For example, the MS series pneumatic precision seeder produced by American Mobosem Company can meet the needs of large plots and farm planting with its seeding effect and efficiency. It can complete all kinds of planting tasks at one time [4~6]. The JP-12 carrot seeder of Korean solant company can complete the earlier land treatment work and subsequent seeding tasks at one time. Now the main domestic seeders are drilling. Machine and precision on demand machine. The drill has the advantages of simple structure, easy use and maintenance, and is suitable for general family. However, it has poor sowing effect, wasted seeds and high planting cost. Precision seeder has the characteristics of high efficiency and high precision. It can be precise to one hole and one grain, basically without seedling thinning. It has better seeding effect and is convenient for mechanized production [7~9].
2. Structural Design and Working Principle
Diesel engine is selected as the alternative, and double-row seeding is adopted. The machine design of this scheme has simple structure, abundant power and is not limited by power. It is suitable for all kinds of complex terrain. It can work in the field for a long time and use double-row seeding. The utilization rate of resources is high and the total amount of work is smaller. This scheme is more efficient and economical than single-row seeding.

According to the previous introduction of the seeder, it is known that the seeder is mainly composed of ditching device, seed metering device and soil covering device, and there are many accessory parts, including rack, transmission device, walking system, etc. The design of seeder is the most important, because the precision requirement of precision seeder mainly depends on the working effect of seeder. The overall structure of the seeder is shown in Figure 1.

![Figure 1. The overall structure of the seeder](image)

The suction hole size of the air suction disc metering device is determined according to the size of the seeds. Generally, the opening is smaller than the diameter of the seeds, so as to ensure that the seeds can be sucked normally. The seeding tray can be used for on-demand, hole and drilling of single seed. Its working principle is that the high-speed fan generates gas flow, generates suction, sucks the seed on the hole of the seed tray, the seed moves with the tray, then scrapes down through the scraping tray, enters the seed delivery pipe, and then falls into the soil. The suction of gas can be adjusted by adjusting the speed of the high-speed fan and the opening size of the ventilation pipe. The seed metering tray can be designed into many different apertures and distributions, and the plant spacing can be adjusted, as well as the rotation speed of the rotating shaft of the seed disc can be adjusted. The advantage of this metering device is that it can sow seeds efficiently and accurately with little damage to seeds and can be used in joint operations with high speed.

The air suction metering device comprises a sealing ring, a metering tray and a box body. As shown in Figure 2.

![Figure 2. Seed metering device construction](image)
metering device plate can be connected with the shaft to provide torque. Its diameter \( d = 220 \text{ mm} \), and its center is a regular hexagon with a side length of \( 16 \text{ mm} \). There are 24 holes with diameter of \( 3 \text{ mm} \) in the circular array. As shown in Figure 3.

![Figure 3. Seed Tray](image)

The design of the hole on the metering plate affects whether the seed can be absorbed normally, and the accuracy of the absorption depends on the hole. So in order to make the absorbed seeds within a reasonable range, the diameter of the hole should be satisfied.

\[
D_z < D_k < 1.5D_z
\]  

(1)

Among them: \( D_z \) is the diameter of the seed.

The seed size of carrot obeys \( D(13.9, 0.056644) \). The precision of general agricultural production equipment is IT7, the maximum deviation of IT7 is \( 0.018 \text{ mm} \). Therefore, \( 6\sigma = 0.018 \text{ mm} \), \( \sigma = 0.003 \text{ mm} \), the diameter of the hole obeys the distribution of \( D_k(\text{mean} = 0.003^2) \).

The principle of reliability allocation is:

\[ R_1 \cdot R_2 \cdot R_3 \cdot R_4 \geq 90\% \]

In formula: 

- \( R_1 \) - Reliability of hole size to fill seeds;
- \( R_2 \) - The reliability of wheel slip is generally 98%.
- \( R_3 \) - The reliability of each part of the seeder is 95%.
- \( R_4 \) - The reliability of the transmission system is generally 98%.

\( R = 99.7\% \).

\[ R_1 = 1 - \Phi(z) = \Phi(-z) = \Phi(z_R) = 0.997 \]

Table lookup is available.

\[ Z_R = 2.75 \]

Therefore

\[
Z_k = \frac{D_k - D_z}{\sqrt{\sigma_k^2 + \sigma_z^2}}
\]

(2)

\[ D_k = 14.5545 \]

(3)

For the convenience of filling seeds, this paper takes \( D_k = 15 \text{ mm} \).

Calculated diameter of equivalent hole, \( D_k = 15 \text{ mm} \), the reliability of seed filling reached 99.9998%. Under the action of gravity, all kinds of box seeds enter the hole. When the measuring
plate rotates and drives the seeds of seed type holes to rotate, under the action of gravity, the redundant seeds fall naturally or come from the guide slot of the hole type, without filling the type holes again, thus realizing the filling process. In order to help seed and seed filling, the channels on both sides of the hole slot are input to improve the continuity and accuracy of filling, and to reduce the impact of injured maize seeds and seeds. If the force of seed guide trough is $N_2$, the force of seed brush is $F$, The coefficient of friction between seeds is $f$, Set the pressure between the seed and the seed is $f_2$, therefor

$$
\begin{align*}
\sum X &= 0 \\
\sum Y &= 0 \\
\sum M (\varphi_2) &= 0
\end{align*}
$$

(4)

$$
\begin{cases}
F \cos \alpha + N_2 \sin (\alpha + \beta) = f_1 N_1 \sin (\alpha + \beta) + N_1 \cos (\alpha + \beta) + f_2 N_2 \cos (\alpha + \beta) \\
mg + F \sin \alpha + f_1 N_1 \cos (\alpha + \beta) = N_2 \cos (\alpha + \beta) + N_1 \sin (\alpha + \beta) + f_2 N_2 \sin (\alpha + \beta) \\
F_h = f_2 N_2 r + f_1 N_1 r
\end{cases}
$$

(5)

In order to minimize the filling time of seeds, the position of the center of gravity of seed filling should be reduced, but the vertical distance should also be reduced to allow the seeds to enter the guide slot smoothly. At the same time, in order to prevent the seeds from being broken in the process of cleaning, we should also ensure that the process of seeds can proceed smoothly. Considering the extreme situation, the seeds are cleared, therefor

$$
N_2 = 0
$$

(6)

Because the structure of this metering device is vertical disc type, the inclination angle is:

$$
\alpha = 30^\circ
$$

(7)

If (3-5), (3-6) are substituted for (3-4), therefor

$$
\begin{cases}
\frac{\sqrt{3}}{2} F = f_1 N_1 \sin (\alpha + \beta) + N_1 \cos (\alpha + \beta) \\
mg + \frac{1}{2} F + f_1 N_1 \cos (\alpha + \beta) = N_1 \sin (\alpha + \beta) \\
F_h = f_1 N_1 r
\end{cases}
$$

(8)

In addition, $h = 2r \sin \beta - r$, after testing and measuring, $f_1 = 0.65$, the friction coefficient will be brought into the above formula for calculation, and the equations will be solved, $\beta = 42.6^\circ$, take into account the actual situation $\beta = 42.6^\circ$.

3. Conclusion

(1) The overall scheme of the seeder is determined, which includes seed metering device, ditching device, soil covering device, pressing wheel, etc. Attention is also paid to the design of the frame and the placement of various parts. Only when these problems are considered comprehensively can the initial overall plan be determined.

(2) SolidWorks three-dimensional modeling is carried out and the preliminary verification of the design results is carried out. With the emergence of problems to change the design. The vegetable
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