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# The design of disengaging mechanism of radix pseudostellariae and soil

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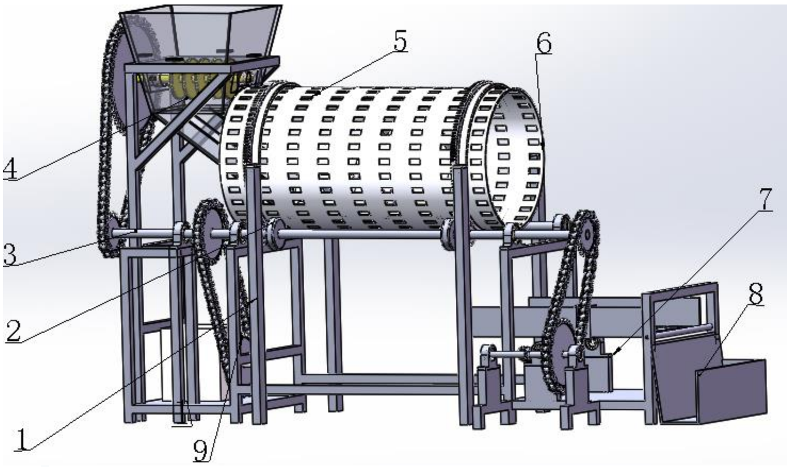
**Abstract**. With the continuous development of the scale of the cultivation of the radix pseudostellariae, the traditional separation mode cannot adapt to the mass production of the crown prince, and the existing manual separation mode is of great labor intensity and low degree of mechanization. Therefore, it is necessary to design a disengaging mechanism of radix pseudostellariae and soil on the basis of the design principle of modern agricultural machinery. According to the physical characteristics and growing environment of radix pseudostellariae, a drum-type separating component is presented, and the drum screen separating mechanism and vibration mechanism of the disengaging mechanism are designed. In this paper, the movement rule and time of the mixture of radix pseudostellariae and soil are determined in the drum screen. Rotation speed of the drum screen is calculated, and the operation rules of the eccentric wheel in the vibration mechanism are summarized.

## 1. Introduction

Radix pseudostellariae have fine wrinkles and fibrous root, and root apex obtuse, the upper part remaining stem scars, the following gradually thin such as rat tail [1]. Zherong, the city in Fujian province, is a plant-intensive areas of Radix pseudostellariae, which still adopts the traditional mode of production and the way of manual excavation and artificial separation. The mode of production labor intensity big, often artificial time-consuming, low production efficiency, needs a lot of labor force, but every household labor are limited, often can't gain Radix pseudostellariae in best harvest time, lead to delay collectiion of Radix pseudostellariae. The disengaging mechanism of radix pseudostellariae and soil can create significant economic effect. Mechanization separation efficiency is a dozen times higher than manual operation. Therefore, it greatly saves the production cost, and it can bring abroad social impact. The mechanical separation greatly reduces the labor force, saves a large amount of human resources, and reduces the labor intensity of workers and promoting workers shift to the second and the third industry [2]. Thus, it is imperative to design a device to separate radix pseudostellariae and soil.

## 2. The general planning for disengaging mechanism of radix pseudostellariae and soil

In this paper, the design of the separating device of radix pseudostellariae and soil consists of five parts, such as the scarification mechanism, the supporting mechanism, the drum screen separating mechanism, dithering mechanism of the separating component and the transmission system. The working principle of this project is as follows: the power of the original moving parts is transmitted directly to the main shaft of the disengaging mechanism, and the original moving part is installed at the end of the discharging device, providing ample space for the feed end. The rotation of the main shaft drives the drum, and the mixture of radix pseudostellariae and soil in the drum screen rotate with the drum, moved along the inner wall of the roller, and it falls off when it move to the highest point. The falling mixtures are struck by the not equidistant cross bar along the axial direction, and the large soils are broken, and then sift out from the hole of the drum screen. In order to help the prince out of the material, make the drum screen at 5 angle to horizontal direction. After sieving, the radix pseudostellariaes are collected by collection device. The structure chart of disengaging mechanism of radix pseudostellariae and soil is shown in Figure 1.




1-support frame 2-support roll 3-the transmission system 4-the scarification mechanism 5-the drum screen separating mechanism 6-locating ring 7-vibration mechanism 8-collecting box 9- diesel engine

**Figure 1.** The structure of disengaging mechanism of radix pseudostellariae and soil

## 3. Design of key parts

### *3.1. Design of the drum screen separating mechanism*

*3.1.1 The movement rule of the mixture of radix pseudostellariae and soil in the drum screen*.The movement of the mixture of radix pseudostellariae and soil in the drum screen can be divided into axial movement and radial motion [3]. In this paper, the axial movement along the roller screen is due to the existence of a certain inclination of the roller screen in the installation, and the conveying speed of the material is consistent with the speed of the drum screen. The radial motion is the circular motion of the material along the inner wall of the drum screen. The centrifugal force required by the circular motion is provided by the drum screen. Obviously, the rotational speed of the material is closely related to the speed of the drum screen.

When the drum rotates at low speed, the material begin to shift along the screen body wall, after move to a certain height, a centripetal force required for circular motion is insufficient to provide the movement that material moves along the wall of the screen, the material will be out of the screen wall in the body as a parabola, the parabolic motion is advantageous to separate radix pseudostellariae from soil. When the rotate speed is too fast, and more than the critical speed, the material will not out of the screen inner wall but along the screen inner wall to continue to do circular motion, makes the material stuck on the inner wall of the drum screen.

Assuming that the drum is rotating counterclockwise, the motion trail of the mixture in the screen wall is shown in Fig. 2. When the material moves to *P* position, the parabolic motion is started, and the motion equation of parabolic motion is:

$$\begin{cases} x = \upsilon t \sin\alpha \\ y = \upsilon t \cos\alpha - \dfrac{1}{2} g t^2 \end{cases} \tag{1}$$

Where x and y are the position coordinates of *P*, *v* is the velocity of *P*, *t* represents the time, g is the acceleration of gravity.

In this moment, the rotational speed for circular motion at *P* point material can be expressed as $n_0 = \frac{30}{\pi}\sqrt{\frac{g\sin\alpha}{R}}$, when $\alpha = 90^\circ$, the critical speed is $n_s = \frac{30}{\pi}\sqrt{\frac{g}{R}}$.

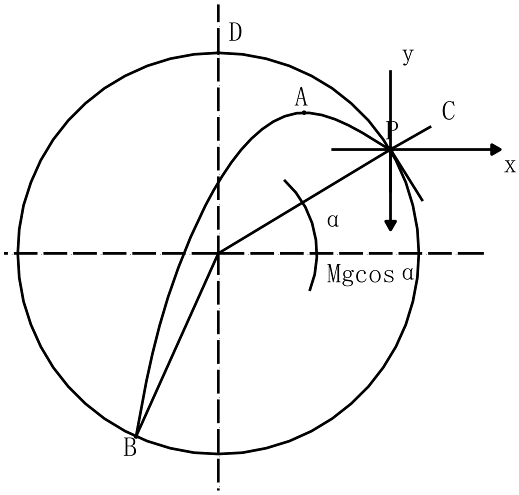



**Figure 2.** The movement trajectories of the mixture in the drum screen

When the material has finished the parabolic motion to the point B, most of them will be screened out, the other not be screened will continue to do circular motion, continuing within the same loop.

Using point P as the origin of coordinates, a rectangular coordinate system is established, and the circular motion equation can be written as:

$$(x + R\sin\alpha)^2 + (y + R\cos\alpha)^2 = R^2 \tag{2}$$

The equation of the trajectory of a parabola is:

$$y = x\cot\alpha - \frac{x^2}{2R\sin^3\alpha} \tag{3}$$

Obviously, simultaneous equations (2) and (3) are not difficult to obtain any intersection of the two curve equations, they is P $(0,0)$ & B $\left(-4R\sin^2\alpha\cos\alpha, -4R\sin\alpha\cos^2\alpha\right)$.

When $r = R$, the material along the inner wall of the cylinder was made circular motion, and the radius of the circular motion was the design radius of the cylinder screen.

When $r \neq R$, the material is removed from the inner wall of the cylinder as a parabolic motion.

*3.1.2 Design of the rotate speed of drum screen*.In order to get an ideal separating effect for the mixture of radix pseudostellariae and soil in the drum screen. There should be enough room for the mixture to roll in the drum screen.

As we can know from the motion curve, making sure the material has a bigger drop when it starts parabolic motion to make that condition sense. The condition is $|y_A - y_B|_{Max}$ [4].

We take the derivative of x of the parabolic equation:

$$\frac{dy}{dx} = \cot\alpha - \frac{x}{R\sin^3\alpha} \tag{4}$$

When $\frac{dy}{dx} = 0$, the null point of equation can be solved $x_0 = R\sin^2\alpha\cos\alpha$

Substitute $x_0 = R\sin^2\alpha\cos\alpha$ into this equation, maximize the parabolic equation:

$$y_{AMax} = \frac{1}{2}R\sin\alpha\cos^2\alpha \tag{5}$$

Formula.6 can be obtained by $f(\alpha) = |y_A - y_B|_{Max}$

$$f(\alpha) = \frac{1}{2}R\sin\alpha\cos^2\alpha + 4R\sin\alpha\cos^2\alpha = \frac{9}{2}R\sin\alpha\cos^2\alpha \tag{6}$$

If $\frac{df(\alpha)}{d\alpha} = 0$, the null point of equation can be obtained $\alpha_0 = arc\cot\sqrt{2} \approx 35.26^\circ$

When $\alpha = 35.26^\circ$, $f(\alpha)$ is maximize. The mixture get the biggest roll space and the separating effect is remarkable. At this point, the drum screen rotate speed is written as

$$n_0 = \frac{30}{\pi}\sqrt{\frac{g\sin\alpha}{R}} = \frac{30}{\pi}\sqrt{\frac{9.8\times\sin 35.26^\circ}{0.25}} = 46r/\min \tag{7}$$

Therefore, the rotation speed of the design drum screen is $46r/\min$.

*3.1.3 The time of the mixture of radix pseudostellariae and soil in the drum screen*. As the drum screen has a certain inclination in the installation, the motion trail of the mixture of radix pseudostellariae and soil in drum screen is helix line. The pitch is:

$$\Delta S = \left|y_P - y_B\right| \tan\beta = 4R\sin^2\alpha\cos^2\alpha\tan\beta \tag{8}$$

In the formula.8, $\beta$ is dip angle of drum screen.

The time required to do a periodic motion of the mixture is $t = t_1 + t_2$

Where $t_1$ is the time required to do a circular motion of the mixture. $t_2$ is the time required to do a parabola motion of the mixture.

The angular displacement required to do a circular motion of the mixture, which mixture moved along the inner wall of the roller, can be solved by the coordinate relation of point P, B and O.

According to cosine theorem of trigonometric function can get the result

$$\cos\theta = \frac{\overline{PO}^2 + \overline{OB}^2 - \overline{BP}^2}{2\cdot\overline{\overline{PO}\cdot\overline{OB}}} = 1 - 8\sin^2\alpha\cos^2\alpha = \cos 4\alpha \tag{9}$$

Obviously, $\theta = 4\alpha$ , so $\angle BOP = 4\alpha$ .

According to the rotate speed, the time required to do a periodic circular motion of the mixture is

$$t_1 = \frac{2\alpha}{3n} \tag{10}$$

The time required to do a parabola motion of the mixture can be solved by the coordinate relation of parabolic equation and point *B*. The time can be shown

$$t_2 = \sqrt{\frac{16R\sin\alpha\cos^2\alpha}{g}} \tag{11}$$

Substitute the equation of the rotate speed of drum screen into the above formula

$$t_2 = \frac{120\sin\alpha\cos\alpha}{n\pi} \tag{12}$$

Therefore, the time required to do a periodic motion of the mixture is

$$t = t_1 + t_2 = \frac{2\alpha}{3n} + \frac{120\sin\alpha\cos\alpha}{n\pi} \tag{13}$$

It is evident that the average velocity of the mixture along the axis direction is $\bar{\upsilon}=\frac{\Delta S}{t}$, and the time of movement of the mixture in the drum screen is $\tau=\frac{L}{\bar{\upsilon}}$. In which, $L$ is the length of drum screen, and installation angles are 4 ~ 8 degrees.

3.2. *Design of dithering mechanism.*
The dithering mechanism includes three parts: an eccentric wheel, a vibrating screen and a support shaft [5]. The dithering mechanism install under the screen surface of the discharge port, cause the screen surface to vibrate by using the irregularity of eccentric motion. On the one hand, the mixture is separated further, On the other hand, and the radix pseudostellariae is gathered into the collecting box.

The working principle of swing follower eccentric wheel is as follow [6]:

According to the change of the radius of curvature, the curvature radius changes uniformly at every

Angle of the eccentric wheel, and then the swing is shifted upward or downward from a certain Angle. Swing follower eccentric wheel is shown in Figure 3.

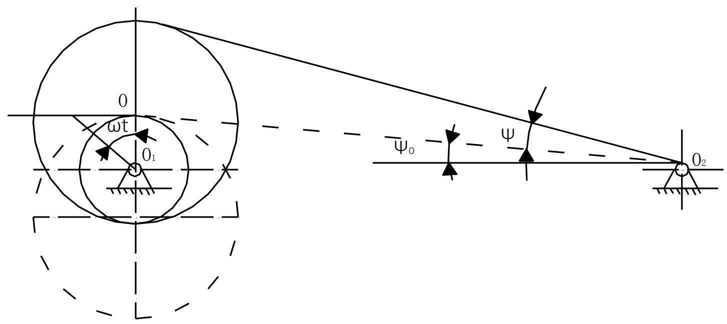



**Figure 3.** Swing follower eccentric wheel

The angular velocity is constant in unit time due to the eccentric wheel rotate constant speed.

The change of angular displacement can be obtained:

$$\varphi=\omega t=\frac{1}{30}\pi nt \tag{14}$$

The angle between the initial position of the follower and the connecting line is:

$$\psi_0=\arcsin\frac{r_b-e}{l_{O_1O_2}} \tag{15}$$

In which, $r_b$ is base radius, $e$ is eccentric distance, $l_{O_1O_2}$ is the center line.

The sail angle of the follower is:

$$\psi_{Max}=\frac{r_b+e}{l_{O_1O_2}} \tag{16}$$

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When the follower deflect to the sail angle, the eccentric wheel spins half cycle time, the angular displacement is $\varphi = \dfrac{\pi nT}{60}$.

Due to the uniform change of the radius of curvature, the deflection rate of the moving parts per unit time is:

$$k = \frac{\psi_{Max} - \psi_0}{\varphi} = \frac{\psi_{Max} - \psi_0}{\frac{\pi nT}{60}} = \frac{60(\psi_{Max} - \psi_0)}{\pi nT} \tag{17}$$

Therefore, the equation of motion in the interval $(0 \le \varphi \le n\pi T/60)$of the follower is:

$$\psi(\varphi) = k\varphi + \psi_0 \tag{18}$$

Since the eccentric wheel is bilateral symmetry on $OO_1$ line, the next half cycle of the follower is also symmetry. So the motion law equation in the interval $(n\pi T/60 \le \varphi \le 2\pi)$ of follower is:

$$\psi(\varphi) = k(2\pi - \varphi) + \psi_0 \tag{19}$$

Through the analysis of experiment, the design parameters of eccentric wheel with oscillating follower are:

The base radius $r_b$=75 mm, eccentric distance $e$=40 *mm*, the distance of the center of gyration of oscillating eccentric wheel $O_1$ to swing center of oscillating follower $O_2$: $l_{O1O2}$=400mm.The length of oscillating follower L=500mm, thickness of the oscillating eccentric wheel :$\delta$=5 *mm*, the rotate speed of he oscillating eccentric wheel:$n$=120 *r/min*, equations of motion of oscillating follower: $\psi = \psi(\varphi)$.

Refer to the reference literature [7], the material of the eccentric wheel is 45 #steel.

According to the known parameters, the rotation cycle of the eccentric wheel is calculated as follow:

$$T = \frac{1}{n}(\min) = \frac{60}{n}(s) = 0.5s \tag{20}$$

The initial swing angle of the follower is computed as follow:

$$\psi_0 = \arcsin\frac{r_b - e}{l_{O_1O_2}} = \arcsin\frac{75-40}{400} = 5^\circ \tag{21}$$

The sail angle of the follower is calculated as:

$$\psi_{Max} = \arcsin\frac{r_b + e}{l_{O_1O_2}} = \arcsin\frac{75+40}{400} = 16.7^\circ \tag{22}$$

The equation of motion of the eccentric wheel can be computed as follow:

$$\varphi = \omega t = \frac{1}{30}\pi n t = 4\pi t \tag{23}$$

Equations of motion of oscillating follower can be expressed:

$$\psi(\varphi) = \begin{cases} \frac{13}{200}\varphi + \frac{1}{36}\pi(0 \le \varphi \le \pi) \\ \frac{13}{200}(2\pi - \varphi) + \frac{1}{36}\pi(\pi < \varphi \le 2\pi) \end{cases} \tag{24}$$

## 4. Conclusion

In this paper, a kind of disengaging mechanism is designed and a feasible scheme which can separate the mixture of radix pseudostellariae and soil automatically is provided. The design of the disengaging mechanism of radix pseudostellariae and soil consists of five parts, such as the scarification mechanism, the supporting mechanism, the drum screen separating mechanism, dithering mechanism of the separating component and the transmission system. In this paper, we mainly analyze the design of the drum screen separating mechanism, including the determination of the movement rule and the drum screen time of the mixture of radix pseudostellariae and soil in the drum screen which rotation speed and power are calculated.

In addition, the motion law of eccentric wheel in the separation mechanism is analyzed, which provides theoretical basis for the vibration separation mechanism.

In the experiment, the design of disengaging mechanism of radix pseudostellariae and soil can separate the radix pseudostellariae from the soil, greatly improve the separating efficiency and reduce the labor intensity of artificial separation.

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## References

[1] B. X. Han, N. F. Chen, Y. Yao, Discrimination of Radix Pseudostellariae according to geographical origin by FT-NIR spectroscopy and supervised pattern recognition, Pharmacognosy Magazine. 20(2009-12-8) 279-286.
[2] M. Q. Lu, Development of small-sized corydalis tuber harvester, Nanjing Agricultural University, Nanjing, 2013.
[3] Z.K.Ding,F.J.Zhou, Z.J. Guan, Design of swill sorting machine components, Journal of Agricultural Mechanization Research. 9(2011) 139-142.
[4] J.L. Sheng, J. Gao, Parameter design of rotating sieve for disposing of garbage, Construction Mechanization, 25(2004) 62-63.
[5] C.C. Weighing Factory, Theoretical Calculation of Eccentric Wheel Design in weighing apparatus, Journal of Jilin University(Science Edition). 11(1976) 49-53.

[6] Z.Q. Zhang,Y. Chang.Structure Design of Vibrating Eccentric and Its Finite Element Analysis, Journal of jiangnan university (natural science edition). 5(2011) 573-577.
[7] B.C. Wang, Mechanical Design Manual, Mechanical Industry Press, Beijing, 2010.