Design and Analysis of Castor Material Cleaner Machine

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Abstract. Castor oil plant is an important oil crop. According to the physical characteristics of castor oil plant to be cleaned, the parameters of feeding hopper, vibrating screen and other components were designed, and the air separation device was simplified in this paper. Secondly, the theoretical cleaning capacity and efficiency of castor oil plant cleaning machine under assumed conditions are calculated, and the selection of motor and belt drive part are calculated theoretically. Finally, the sheet metal design and angle iron forming are used to conduct three-dimensional modeling design for the two parts, and the simplified model of the screen body drive mechanism is analyzed through the motion to find out the basic laws of the screen body movement. By studying the kinetic characteristics of castor bean, the aerodynamic equation and kinematics equation of castor bean were established. This study can provide a theoretical basis for the development of castor oil plant cleaning equipment.

1. Introduction
Castor is a very important plant in the world. Castor oil is used to lubricate aerospace machinery.

The research and production of castor oil plant and other grain cleaning machinery started late in China. The first prototype was introduced in the 1950s. The earliest products were manual windmill and slide screen with low productivity and poor cleaning effect. On the basis of introducing and digesting foreign advanced cleaning machinery technology, it developed grain cleaning and processing machinery with a certain advanced level. In the 1990s, new technologies, new products and new technologies emerged continuously, providing technical guarantee for the development of grain cleaning and processing industry [1-3]. After more than half a century of development, it has basically formed a processing system with Chinese characteristics, adapted to the needs of our users, complete varieties and specifications, and self-research and production. For example, the sn-zx80 multi-grain shaker produced by Shandong snow machinery equipment co., ltd. can screen castor materials with a net separation rate of up to 95% [4-5]. According to the results reported by farmers, the main performance indexes of the grain cleaner on the market in the process of castor bean cleaning can meet the requirements of the explicit implementation standards of enterprises, and can basically meet the needs of users [6-7].

2. Cleaning principle and overall design
The cleaning machinery main working parts as the screen on the second floor and the fan, containing castor beans, sand, scrap foam of straw, chaff of castor after cleaning material into the feed port directly after equipped with fan casing first blow away the light weight of leaf, castor stalk crumb foam light, dust and other miscellaneous waste, and connect to accept bag in the body side, acceptance after the fan
blowing out the light impurities, and connect to accept bags have a mesh screen, avoid the castor bean had light impurity was the fan blowing out of the box body; The castor bean to drop at the beginning of the upper sieve sieve cleaning material after vibrating screen points, impurities such as large piece of gravel particles legacy on the screen, and castor bean and small particles of mixed impurity drops on the lower fine sieve sieve, sieve net will lower the castor material of small miscellaneous, small stones, severely damaged grain directly to miss, full and mild damage of castor beans will came out from the discharging mouth screening, and serious damage of grain, along with small particles impurities, will serve as fertilizer returning secondary recycling, in order to play its surplus value.

2.1. Aerodynamic characteristics of castor bean materials
When castor bean initial velocity $v_0$ is 0.8$m/s$, Initial direction angle $\delta$ is 0°, fan speed $u$ is 7$m/s$, when the flow direction angle $\beta$ is 10°, Only light impurities in castor beans to be cleaned are blown out of the box.

2.2. Mechanical properties of castor bean materials
According to the experimental measurement, the dynamic friction factor between castor bean and Q235 carbon steel is 0.2, the dynamic friction factor between castor bean and Q235 carbon steel is 0.51.

3. Design principles of key components

3.1. Sliding condition of castor bean material along the inclined surface of the hopper
Check the agricultural machinery design manual", as shown in figure, a grain of quality for m castor beans, placed on the inclined Angle of theta, and friction Angle of the inclined plane as $\Psi$, f is the friction:

Figure 1. Diagram of castor oil plant cleaning structure

Figure 2. Analysis diagram of castor bean sliding down the hopper
When \(mg \sin \theta > f\), \(mg \sin \theta > mg \cos \theta \tan \Psi\), then \(\tan \theta > \tan \Psi\), then \(\theta > \Psi\).

By the formula, and the experiment measured the friction factor of Q235 carbon steel \(\mu = 0.2\), the castor beans and the friction Angle of the inclined plane \(\Psi = 11.3^\circ\), considering the influence of other impurities, the initial into the hopper are angled slant and horizontal \(= 15^\circ\) layout. 3.2 Hopper design for castor shelling machine

When the castor bean initial speed of 0.8 m/s, the initial direction Angle of 0°, fan air velocity \(u\) for 7 m/s, airflow direction Angle of beta is 10°, castor beans for cleaning of outside only light impurity was blown out of the box body. Therefore, castor bean must reach the initial speed of 0.8m/s at the end of the sliding distance into the hopper. As shown in figure 3.2, if the component force of gravity downward along the inclined plane is \(F\), and the magnitude is equal to \(F = mg \sin \theta\), then the acceleration is:

\[
a = \frac{F}{m} = \frac{m g \sin \theta - mg \cos \theta \tan \Psi}{m} = g (\sin \theta - \cos \tan \Psi)
\]

Then: \(a = 1.407 \text{ m/s}^2\)

The length of the inclined plane of the hopper is 0.25m, the castor bean gains speed to the bottom of the ramp \(v\) is 0.82m/s. To ensure that castor beans into the fan box in the initial direction of the Angle \(\delta\) is 0°, A horizontal buffer is designed at the end of the inclined plate to ensure the initial speed of the castor bean is \(v_0 = 0.8\text{m/s}. \) Initial direction Angle \(\delta\) is 0°. The castor bean exerts only gravity on the horizontal surface \(G\), The frictional force \(f\) and support \(F_n\). Kinetic friction factor \(\mu\) is 0.2, and \(a' = \mu g = 1.96\text{m/s}^2\), Based on \(v_0 = v - at'\) then \(t' = 0.01\text{s}\), The horizontal buffer must have a length is:

\[
L = vt' - 0.5a't'^2 = 0.008\text{m}
\]

Castor seeds and small impurities fall on the lower fine sieve after the coarse sieve of the upper sieve, the lower vibrating sieve net will be castor materials in the small impurities, small stones, and severely damaged seeds directly missed, intact castor seeds and slightly damaged seeds, not full seeds will be screened from the outlet. Because the size of severely damaged grains and small impurities is smaller than that of other types of grains in three directions, the shape of the sieve hole can be selected as a round sieve. The mesh size is 40, the diameter of mesh \(d = 4\text{mm}, \) the spacing of the holes \(t = 6\text{mm}, \) and the thickness of the mesh is 2.0mm. The arrangement is shown in figure 3-4.

3.2 Determination of screen surface inclination

In principle, in order to make the machine has greater adaptability, the inclination of the screen surface is sometimes designed to be adjustable, but because this design is only for castor bean cleaning, so directly set the inclination of the upper and lower screen surface as a fixed value. According to the agricultural machinery design manual screening machine part of the main parameter selection and determination, in grain crop seed cleaner, basic cleaning, sieve sieve surface inclination Angle on the range of \(5-10^\circ\), the sieve sieve surface for \(10-15^\circ\). According to castor seeds for seeds oblong shape, its liquidity, so Angle should choose larger value, namely the sieve sieve surface inclination Angle on the selection of \(7^\circ\), sieve sieve surface under Angle is \(15^\circ\), choose reasonable.
3.3. The critical condition for castor bean to slide down the sieve surface

In order to simplify the problem, the force between castor beans to be cleaned was neglected.

On sieve sieve surface inclination of alpha = 7°, castor bean by force of gravity, inertia force Q, G screen surface binding N and friction force F.

\[ N = G \cos \alpha - Q = mg \cos \alpha - mw^2 \omega \sin \alpha \]  

The critical condition for castor beans to slide down the screen is:

\[ Q \cos \alpha + G \sin \alpha \geq F \]  

\[ w^2 \omega \sin \alpha \geq \tan(\Psi - \alpha) \]  

Because \( \cos \omega t \) Absolute peak value is 1, \( w = \pi n / 30 \)

Then castor bean along the screen surface slide of the crank critical speed is:

\[ n \geq 30 \sqrt{g \tan(\Psi - \alpha) / \pi^2 r} \text{ r/min} \]  

In it, the upper screen surface inclination \( \alpha = 7^\circ \), Lower sieve surface inclination \( \alpha = 15^\circ \), \( n \) is the crank speed per minute, \( \Psi \) is The friction Angle between castor bean and sieve surface is 27°, \( m \) is the single grain weight of castor bean, \( g \) is 9.8 m/s^2, \( \pi \) takes 3.14, \( r \) is the average width of castor beans, takes 0.006m, then:

\[ n_1 \geq 30 \sqrt{9.8 \times \tan 20^\circ / 3.14^2} \times 0.006 \text{ r/min} = 236.22 \text{ r/min} \]

\[ n_2 \geq 30 \sqrt{9.8 \times \tan 12^\circ / 3.14^2} \times 0.006 \text{ r/min} = 179.78 \text{ r/min} \]

Then castor beans along the upper sieve surface of the crank down the critical speed \( n_1 \) is 236.22r/min, The critical speed of the crank sliding down the screen surface \( n_2 \) is 179.78r/min, The vibration frequency of the equipment can be reached 320r/min, then it can run along with the upper and Lower sieve surface slides.

3.4. Calculation of the pass rate of vibrating screen

Vertical vertical pass rate, is the main index to evaluate the work quality of plane screen, and its expression is:
\[ \eta = \frac{W}{q\lambda} \times 100\% \] (8)

In it: \( W \): The quality of the material passing through the planar screen in unit time 
\( q \): The total mass of the material flowing into the plane screen in unit time is the feed quantity. 
\( \lambda \): Pass rate coefficient refers to the ratio of the mass of materials that should pass through the sieve hole to the total mass of materials on the sieve surface.

\( \eta \): The larger the value is, the better the performance of the vibrating screen.

\[ \eta = \frac{W}{q\lambda} \times 100\% = 97.5\% \] (9)

Calculation of the pass rate of vibrating screen Vertical vertical pass rate is the main index for evaluating the working quality of a plane sieve. Its expression is:

\[ \eta = \frac{W}{q\lambda} \times 100\% = 97.5\% \] (10)

In the formula: \( W \): material quality passing through the planar sieve hole in unit time; \( q \): the total mass of materials flowing into the plane screen in unit time, namely the feeding quantity; \( \lambda \): pass rate coefficient refers to the ratio of the mass of materials that should pass through the sieve hole to the total mass of materials on the sieve surface.

4. Simulation of clean process

The larger the value is, the better the performance of the vibrating screen. Hypothesis after cleaning air separation unit, fell 95% in the material on the upper vibrating screen of castor beans for cleaning materials, 5% of the sand impurity, after the upper vibrating screen to screen after 98% of castor beans fall on the lower screen, 2% of small sand, clod drops on the lower screen, a value is set to 1, generation into the formula 3-10, the mesh pass rate:

(1) When the initial velocity of the particle is 0m/s, the airflow velocity is changed, and the particle trajectory is shown in FIG. 5-5. A shows the glume shell particle trajectory, b shows the castor bean seed trajectory.

Figure 5. Different particle trajectories as 8m/s

Figure 6. Different particle trajectories at 10m/s
5. Conclusion
Through the design of castor oil plant cleaning mechanism, the following conclusions are drawn:

Before the light impurities are blown out of the air separation section, 40 circular whole sieve pieces are added to block the screen screen to prevent castor materials from being blown out of the box except for impurities. The selection of fan specifications reduces the requirements and is simple and easy to operate. The theoretical productivity of the upper sieve of the vibrating screen is 213.51kg/h, and the theoretical productivity of the lower sieve is 163.16kg/h.

The motion trajectory of castor seeds was simulated and analyzed. The cleaning chamber model was established, the airflow field distribution and inlet velocity were simulated, and the simulation results were analyzed intuitively. The parameters affecting the separation quality were determined as follows: when the inlet airflow velocity was 8m/s and the initial velocity of the shell was 0m/s, the best cleaning effect could be achieved.

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