ISSN 2706-655X Vol. 7, Issue 4: 45-50, DOI: 10.25236/IJFET.2025.070407

Design of Automatic Taro Peeling Machine

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Abstract: *To address the issue of insufficient mechanization and low efficiency in taro peeling, an automatic taro peeler was designed. The design of the main structural components of the taro peeler, including the position correction mechanism, lifting platform, transmission mechanism, and cutting knife, as well as the calculation of the main working parameters of the automatic taro peeler, were completed. This machine can perform taro peeling, waste material recovery, and finished product collection, reducing labor costs.*

Keywords: *Taro; Peeling of Fruits and Vegetables; Agricultural Machinery*

1. Introduction

Taro is a perennial tuber plant. At the base of the plant, a short stem is formed, gradually accumulating nutrients and swelling into a fleshy bulb, which is called "taro" or "mother taro", presenting shapes such as spherical, oval, ellipsoidal or blocky. Taro is rich in nutrients and is a crop that can be used both as food and medicine, with high nutritional and therapeutic value[1~2]. With the improvement of people's living standards, the demand for taro has also increased significantly.

The first step in processing taro is to remove its skin. Currently, the peeling process of taro in the market is mostly carried out manually. However, taro has a thick skin and an uneven surface with wrinkles, and the raw taro juice can cause local skin allergies, making the skin extremely itchy and uncomfortable, and easily causing irritation to the skin. All these bring great inconvenience to the peeling process of taro, making the peeling technology for taro inefficient and unable to meet the requirements of large-scale, high-efficiency production in the industry. With the development of agricultural mechanization, the application of food processing equipment in the processing of fruits and vegetables has significantly improved production efficiency and greatly reduced the reliance on manual operations.[3] Over the past few years, various types of taro peeling machines have been gradually introduced to the market, with knife peeling and friction peeling being the representatives. However, these peeling machines still have shortcomings such as not being able to operate continuously or not peeling thoroughly. Therefore, designing a taro peeling machine that can achieve continuous operation is necessary.

2. Overall structure and working principle

Based on the mainstream taro peeling machines available on the market, the design of this peeling machine adopts the knife-cutting method as the peeling technique. A positioning corrector is added to push the taroes into the peeling area one by one through the push rods, achieving automatic taro peeling and reducing labor costs. The overall structure of the taro peeling machine is shown in Figure 1. It mainly consists of a positioning correction device, a lifting adjustment platform, and a transmission cutting system. The positioning correction mechanism is placed on the upper part of the machine box, making it convenient to insert the taroes. During operation, clean and appropriately sized taroes are poured into the drum of the positioning correction mechanism, and the taroes with correct positioning will roll down into the sliding channel below one after another. The bottom sliding door is pushed open, allowing a taro to enter the lifting platform. The lifting platform is responsible for adjusting the long axis of the taro to be at the same height as the push rod. Then, the transmission mechanism pushes the left and right push rods to clamp the taro and rotate it before bringing it into the cutting area to complete the peeling process. The push rod lowers the taro in the blanking area and returns to its

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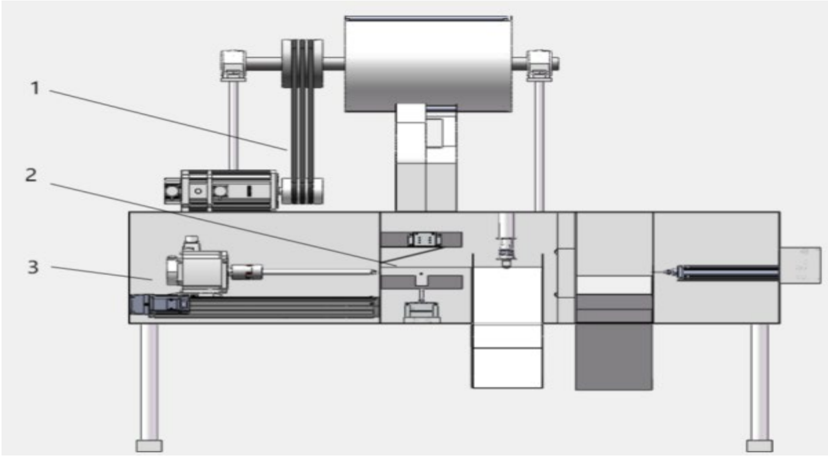
original position, completing one peeling operation.



1 - Position correction institution; 2 - Lifting adjustment platform; 3 - Transmission cutting system.

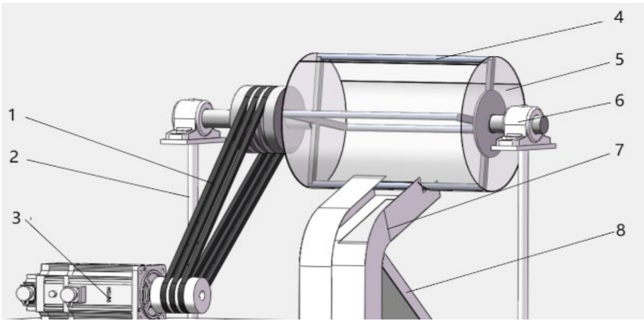
Figure 1: Structure diagram of taro peeler

3. The main structure of the taro peeling machine

3.1 Position correction device

The position correction mechanism is shown in Figure 2. Its main components include the drive motor, circular outer barrel, stirrer, belt drive group, fixed bearings, and support rods.

The support rods are connected to the rear part of the machine box, providing support for the entire mechanism. The belt drive structure is simple, smooth in operation, capable of buffering and absorbing vibrations, low in cost, does not require lubrication, and is easy to maintain. V-belt drive is selected as the transmission method between the drive motor and the stirrer. [4]The two ends of the stirrer are fixed with rolling bearings to reduce the friction between the contact surfaces, making the stirrer operate more smoothly and stably. The circular outer barrel remains stationary, and a rectangular opening is provided at the bottom for the falling of the taro.



1 - Belt drive group; 2 - Support rod; 3 - Drive motor; 4 - Blender; 5 - Circular outer cylinder; 6 - Fixed bearing; 7 - Slide; 8 - Recycling channel

Figure 2: Position correction device

During operation, the motor drives the agitator through belt transmission, causing the taro in the circular outer cylinder to rotate continuously. When the long axis of the taro is parallel to the long rectangular opening at the bottom, the taro rolls down into the lower chute. This process is carried out at a low speed and does not cause damage to the surface and internal structure of the taro.[5] Due to the characteristic of the taro being larger in the middle and smaller on both sides, a hollowed-out design is made at the center of the chute bottom to effectively prevent the taro from tilting during the falling process and maintaining a horizontal rolling state. At the same time, when the taro does not fall horizontally in the chute, it will fall through the hollowed-out part, and a collection channel is set at the rear of the chute for unified collection to prevent the taro from scattering and increase the workload of subsequent manual work. A cover plate is set on the left side above the chute to prevent the taro from rolling out of the chute during the falling process. On the right side, there is an opening without a cover

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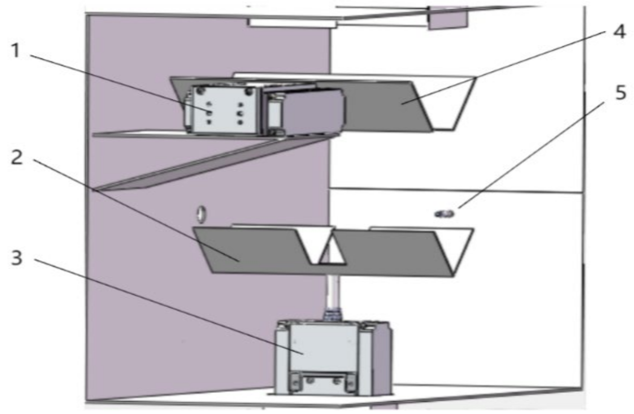
plate, allowing one to observe whether the taro enters the lower stacking area in a horizontal state. If the position of the taro during the falling process shifts or gets stuck, it can be manually corrected through the opening on the right side to ensure that the taro enters the designated stacking area in a horizontal state as required.

3.2 Elevating Adjustment Platform

The lifting adjustment platform is shown in Figure 3. It mainly consists of an electrically operated opening and closing door, a bottom support platform, and an infrared distance sensor. The electrically operated push-close door is located at the bottom of the correction mechanism slide track, and it is distributed in a V-shaped pattern with the front and rear sections being larger at the top and smaller at the bottom. Each section is powered by a separate driving motor.

When the push-in door is opened, the taros fall down to the lower receiving platform due to gravity. At the same time, due to the presence of the first taro on the lower side and the left and right obstructions on both sides of the push-in door, the excess taros will continue to stack inside the push-in door. When closing, the two side motors move inward at the same speed. Through the V-shaped design of the inclined angle on both sides, the push-in door generates longitudinal force to push the taros upwards, leaving only the ones ready for cutting. The lower receiving platform is also of V-shaped design, which ensures that the long axes of different-sized taros are located on the same plane. The empty slot in the middle of the receiving platform enables the distance measurement system to detect the surface of the taros.



1 - Drive the motor; 2 - V type connection; 3 - Bottom motor; 4 - Sliding door; 5 - Infrared sensor

Figure 3: Lift and adjust the pavilion

The distance measurement system uses infrared distance sensors for distance detection. These distance sensors have a relatively short measurement range but offer higher accuracy compared to other sensors, which meets the requirements of this machine.[6] Combined with the elliptical shape and wide middle part of the pumpkin, the measurement value of the infrared sensor also changes linearly during the slow lifting process. When it reaches the extreme value, the lifting platform stops moving. At this point, the long axis of the pumpkin is aligned with the push rod, which can enhance the stability of subsequent push rod clamping and the uniformity of rotational cutting.

3.3 Transmission peeling system

The transmission system is shown in Figure 4, which includes a solid lead screw slide table, a rotating motor, an electric push rod, and a spring cutting knife. It is responsible for clamping the taro to make it rotate and complete the peeling work through the cutting knife, and it is the main working component. The left push rod is connected to the rotating motor through a coupling, and is responsible for driving the taro to rotate. The head of the left push rod is designed in a triangular spike shape, which can better fix the taro and transfer greater rotational force during the rotation of the taro. The ball screw transmission system is widely used in various equipment, enabling the rotational motion to be very precisely converted into linear displacement. The rotating motor is installed on the lower lead screw slide, and the push rod can move left and right.[7] The electric push rod is installed on the right side. As the driven push rod, it is responsible for fixing the taro. Its head is equipped with a long spike, which can penetrate the interior of the taro, ensuring that the taro does not fall off during the peeling

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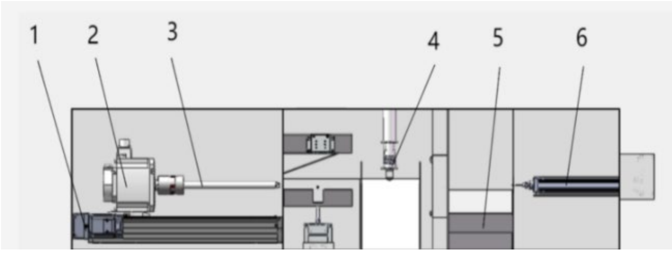
process.

The cutting tool comes into direct contact with taro, so it should be resistant to rust. Therefore, stainless steel is used for the cutting tool.[8] The blade is divided into two layers, upper and lower. By adjusting the distance between the two blades, the thickness of the peel can be controlled, reducing the waste caused by excessive cutting. The arc-shaped design on both sides avoids the possible jamming of the blade when it forms a vertical angle with the taro. A spring device is installed at the bottom of the cutting blade, which can adapt to the irregular shape of the taro and different cutting conditions. When the spring is compressed, it can freely extend and contract, providing sufficient float for the tool, ensuring that the blade always adheres to the surface of the taro. This guarantees uniform peeling for most of the same variety.[9]



1 - Lead screw slide table; 2 - Rotating motor; 3 - Left putter; 4 - Cutting tool; 5 - Collection Channel; 6 - Electric push rod

Figure 4: Transmission cutting system

When starting, the left and right push rods move to grip the taro. The motor is turned on to start the rotation of the taro. The two push rods move to the right at the same speed. The speed of the push rods' movement is adjustable in stages. After the taro reaches the cutting area, the speed of the push rods is reduced to improve the cutting effect. When it reaches the finished product area, the taro is blocked by the barrier and detaches from the push rods, falling into the collection channel.

4. Parameter design of taro peeler

4.1 Belt Drive Parameter Design

The belt drive system, as the core component for power transmission in the taro peeling machine, its design rationality directly affects the stability, efficiency and reliability of the entire machine's operation. This section conducts a detailed design and calculation of the belt drive system.

The design power is determined based on the required power of the transmission system and considering the working condition coefficient:

$$p_d = K_A \cdot P \tag{1}$$

p_d =design power(kw)

p =Calculate the power of the transmission system= 1.98kw

K_A=working condition coefficient=1.2

According to the application characteristics of agricultural machinery, the working load of the taro peeler is moderate impact, with a daily working time of 8 to 10 hours and a working condition coefficient of 1.2.[10]

Hence,

$$P_d = 1.2 \times 1.98 = 2.376kW$$

$$P_d = 2.376kW$$

Based on the design power and the rotational speed of the driving wheel (taking the rated rotational speed of the motor 1440 r/min), type A V-belts are selected. The base diameter of the driving wheel must meet the minimum diameter requirement, and the base diameter of the driving wheel should be selected according to the standard size series. The base diameter of the driven wheel is determined by the transmission ratio:

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$$d_{d2} = i \cdot d_{d1} \cdot (1 - \varepsilon) \tag{2}$$

$$i = \frac{n_1}{n_2} \tag{3}$$

d_{d2}=driven wheel diameter(mm)

i=transmission ratio

d_{d1}= driving wheel diameter(mm)=100mm

ε=sliding ratio,take 0.01 to 0.02

n_1=drive wheel speed(r/min)=1440 r/min

n_2=driven wheel speed(r/min)=500r/min

Hence,

$$i = \frac{1440}{500}$$

$$i = 2.88$$

$$d_{d2} = 2.88 \times 100 \times (1 - 0.02)$$

$$d_{d2} = 282.24mm$$

It can be calculated that the standard diameter of the driven wheel is 280mm.The belt speed should be within a reasonable range of 5~25 m/s.

$$v = \frac{\pi \cdot d_{d1} \cdot n}{160 \times 1000}$$

$$v = 7.54m/s \tag{4}$$

The belt speed is moderate and meets the requirements.

The initially determined center distance needs to meet:

$$0.7(d_{d1} + d_{d2}) \le a_0 \le 2(d_{d1} + d_{d2}) \tag{5}$$

a_0=center distance

According to the overall layout of the machine, the initial center distance is 500mm.

4.2 Mechanical Analysis of Cutting System and Design of Spring Parameters

The cutting mechanism is the core executive component of the taro peeler, and its performance directly determines the peeling quality and efficiency. The cutting tool needs to maintain a constant cutting force on the surface of the taro to cope with the irregularity of the taro's geometric shape. The cutting force should be sufficient to cut through the taro skin but avoid cutting too deeply into the taro flesh. Based on the agricultural machinery cutting force calculation model and in combination with the physical characteristics of taro, the cutting force calculation formula is:[11]

$$F_c = K_c \cdot \delta \cdot f \tag{6}$$

F_C=cutting force

K_c=unit shear force

δ=peeling thickness

f=feed

The total stiffness of the spring system is satisfied:

$$K = \frac{F_c}{x_{max}} \tag{7}$$

K= spring total stiffness

F_C=cutting force

x_{max}=spring maximum compression

4.3 Power and Torque Calculation of the Transmission System

The transmission system needs to achieve the rotational and axial feed motion of the taro, and its power output must overcome cutting resistance, mechanical friction and inertial load.The output power can be estimated by the following formula:

$$P_m = \frac{F_C \cdot \pi \cdot D \cdot n}{\eta} \tag{8}$$

P_m=output power

F_C=cutting force

D=diameter of taro

n=otational speed of taro

η=transmission system efficiency

5. Conclusion

This paper designs an automatic taro peeling system, which mainly consists of three parts: position correction device, lifting adjustment platform and transmission cutting system. The structure is simple and the operation is convenient. The position correction system can achieve continuous peeling of taro one by one. The knife peeling method can ensure the peeling effect, improve the cutting effect and reduce labor costs, bringing a new mechanized solution to the taro peeling work that mainly relies on manual peeling.

Acknowledgement

This work was supported by the National Level College Students' Innovation and Entrepreneurship Training Program (202410595065).

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