Design and Research on Integrated Equipment for Cleaning and Packaging of Baby Cabbage

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Abstract: In view of the continuous expansion of the baby vegetable industry in China, but the postpartum root cutting, leaf peeling, packaging and other processing processes are highly dependent on labor, the lack of dedicated complete sets of integrated processing equipment, high mechanical damage rate, poor standardization of finished products and other industrial pain points, combined with the plant size, single ball quality and different mechanical properties of various parts of baby vegetable, a baby vegetable cleaning and beating machine integrating self weight clamping, rotary root cutting, spiral kneading and leaf peeling, and intelligent heat sealing and packaging is developed. The whole machine adopts a double-layer symmetrical three-dimensional compact layout, and is divided into five collaborative operation function modules: clamping, rooting, defoliation, transmission and packaging; It innovates the compound defoliation structure of self weight clamping mechanism driven by no external force and gravity drop, and uses a single motor shunt multi-stage transmission system to realize multi station power synchronous output; The packaging closed-loop control system is built with STM32 microcontroller as the core, and the photoelectric sensor and stepper motor linkage are used to complete the automatic operation of material identification, film conveying and heat sealing cutting. Through the motor power matching, V-belt, gear transmission design and the verification of high-speed, intermediate and low-speed three-axis bending and torsion strength, the mechanical properties of the whole machine meet the requirements of long-term continuous operation. The actual processing performance shows that the equipment can replace 2-3 operators, and the processing efficiency is twice as high as that of manual operation. The equipment has low cost and small space occupation. It is suitable for small and medium-sized vegetable processing enterprises, and fills the technical gap of domestic baby cabbage whole process automatic processing equipment, providing design ideas and theoretical basis for the research and development of leaf vegetables postpartum intelligent processing equipment.

Keywords: Baby Cabbage; Integrated Processing Equipment; Self Weight Clamping; STM32 Control System;

1. Introduction

Baby cabbage is an important cash crop in China's leafy vegetables. Because it tastes sweet and crisp, the market demand in the field of fresh consumption and prefabricated vegetable processing continues to grow. Industry data show that in 2025, the planting area of baby cabbage in China is expected to exceed 1.8 million mu, the market scale will exceed 40billion yuan, the compound annual growth rate will remain above 10%, and the industrial expansion trend will be significant. However, at present, the postpartum processing of baby cabbage in China is still dominated by manual operation, and the processes such as root cutting, leaf peeling and packaging are independent and decentralized. There are many problems such as high labor intensity, low production efficiency, insufficient product standardization and high mechanical damage rate of dishes, which have become the core bottleneck restricting the scale and quality upgrading of the industry. From the perspective of the development status of vegetable processing equipment in the world, developed countries such as Europe, America and Japan have formed a relatively complete automatic processing technology system for leafy vegetables. The spiral vegetable cleaning system of Kronen company in Germany, the intelligent sorting and packaging line of GEA company, and the high-speed vegetable packaging machine of

Teraoka in Japan have obvious advantages in processing efficiency and intelligent level, but there are problems such as high cost and high operation and maintenance cost, which are difficult to meet the actual needs of domestic small and medium-sized processing enterprises. The domestic vegetable processing equipment has developed rapidly in recent years, but the research and application are mostly focused on the general equipment of rhizome vegetables, and the research and development of special equipment for baby vegetables and other characteristic leafy vegetables is insufficient; Most of the existing commercial equipment are single function models such as cleaning and packaging. The connection between processes highly depends on manual transfer, and the overall integration and automation level are low. In view of the above industrial pain points, combined with the strategic guidance of China's smart agriculture and agricultural mechanization development [1,2,3], this paper designs a postpartum integrated processing equipment for baby cabbage, which integrates root removal, defoliation, cleaning treatment and packaging. Based on the analysis of the material characteristics and processing technology requirements of baby cabbage, this paper completed the overall scheme and core mechanical structure design of the whole machine, built an automatic control system, and verified the rationality and reliability of the equipment design through mechanical calculation and strength verification, in order to fill the technical gap of the integrated processing equipment of baby cabbage in China, and provide technical reference for the localization and upgrading of leaf vegetables postpartum processing equipment.

2. Analysis on Processing Technology of Baby Cabbage

2.1 Analysis of Physical Characteristics of Baby Cabbage

The geometric shape, yield and variety characteristics of baby cabbage are the core input basis for the structural design of the whole machine. Combining with the test data of commercial baby cabbage varieties in high cold and cool production areas, and taking the mainstream cultivated varieties in the market as the sample reference, the single ball quality range of the tested high-quality varieties is 627.33~1384.33g, among which the average single ball quality of fine varieties such as wasp suitable for large-scale processing is about 1138.5g, the plant type ball height is about 19.50cm, and the ball width is 13.24cm. There are significant differences in leaf length, ball diameter, and unit weight among different varieties; At the same time, the number of outer leaves of each variety is distributed in 8~11 pieces, and the different proportion of outer leaves will directly affect the working load of the defoliation mechanism. The difference characteristics of different varieties' growth characteristics, nodulation morphology and yield per plant showed that the material shape and weight dispersion of baby cabbage were large, so the equipment clamping, cutting and defoliation unit must have the ability to adapt to the wide range of materials, and be compatible with the continuous processing of commercial baby cabbage with different plant types and unit weights.

From the point of view of physical and mechanical properties [4], the mechanical properties of different parts of baby cabbage are significantly different, which directly determines the selection of corresponding processing methods: first, the root fiber tissue is brittle and hard, and the tissue is uniform, which is suitable for rotary cutting to complete the root removal process; In the continuous cutting operation, the contact process between the blade and the root is stable and the force is uniform, which can not only obtain a flat and smooth incision, but also avoid the material stress dislocation and flying out of the fixture that are easy to occur in the punching and cutting process, and adapt to the operation rhythm of the continuous production line at the same time; Second, the outer protective leaf has strong toughness and weak connection with the base of the leaf ball, which can be peeled by mechanical effects such as impact and rubbing, and is not easy to damage the internal edible tissue; Third, the inner edible leaf ball tissue is crisp and tender, with poor extrusion resistance, and is prone to mechanical damage when pressed or torn by external forces, which puts forward strict restrictions on the flexibility and strength of the processing mechanism. Based on the above characteristics, the equipment needs to meet the triple design requirements of accurate rotary cutting of the root, efficient stripping of the outer blade and nondestructive protection of the inner blade ball.

2.2 Traditional Processing Technology and Existing Problems

The postpartum processing of traditional baby cabbage adopts the manual assembly line operation mode, and the process is shown in the following figure1.

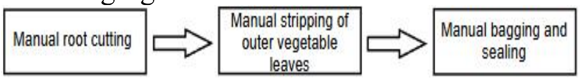

Figure 1. Flow Chart of Traditional Manual Operation

There are three core problems in this process mode:

1) The production efficiency is low, the processing capacity of single work order is limited, large-scale production requires a lot of labor, and the labor cost is high;

2) The product is poorly standardized, the length of manual root cutting and the degree of leaf peeling vary from person to person, and the consistency of finished product specifications is insufficient, which affects the value of goods;

3) The damage rate of the dish is high, and the manual operation force is difficult to accurately control, which is easy to cause excessive cutting blade ball damage, central column fracture and other conditions, and reduce the qualified rate of finished products.

2.3 Equipment Processing Process Requirements

Combined with the actual needs of the industry, the equipment needs to meet four core process requirements: first, continuous operation, realizing the automation of the whole process from raw material rooting to finished product packaging, and reducing manual transfer links; The second is non-destructive processing. The root cutting incision is flat, and the inner blade ball is not damaged in the defoliation process, so as to ensure the quality of the finished product; The third is wide adaptability, which can be compatible with baby dishes of different sizes and specifications, and adapt to individual differences of raw materials; Fourth, it is food grade safety. The parts in contact with the vegetable body should meet the hygienic standards for food processing, which is convenient for cleaning and disinfection.

3. Overall Design of Baby Vegetable Cleaning and Packaging Machine

3.1 Overall Layout Scheme

The equipment adopts a symmetrical three-dimensional overall layout scheme, which is divided into two layers. The upper layer is the pretreatment processing layer. The pretreatment process is realized through the characteristics of baby cabbage raw material, such as large volume, self weight and similar to cylindrical bar shape, and relying on gravity clamping and conveying and high-speed root removal processing. The symmetrical three-dimensional arrangement on both sides is shown in Figure 2 [5]. Through the impact caused by the height difference of the two-layer conveyor belt and the part of the spiral defoliation stopper, the dual station parallel operation is realized; The intelligent packaging unit is integrated in the middle of the lower layer to complete the final packaging process. The layout scheme has the advantages of high space utilization, compact structure and small floor area. At the same time, the gravity is used to realize the material flow between processes without additional lifting of the conveying device, which simplifies the structure of the whole machine.

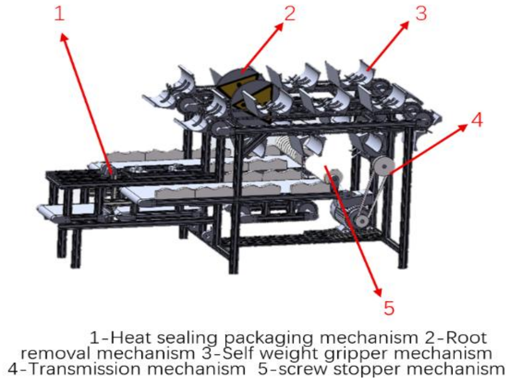

Figure 2. Three Dimensional Structure of the Whole Machine

3.2 Functional Module Division

The whole machine is divided into five core modules according to its functions, as shown in Figure 3 below: first, the self weight clamping module realizes the automatic clamping and positioning of baby cabbage; The second is the high-speed root removal module, which completes the precise cutting and removal of the root; The third is the spiral stopper module, which realizes the stripping and sorting of the outer old leaves; The fourth is the transmission module, which is connected in series with each process to ensure the consistent tempo of material flow; Fifth, the intelligent packaging module completes the film heat sealing packaging of the finished product. Each module is designed independently and cooperatively, and unified scheduling is realized through the transmission system and control system [6].

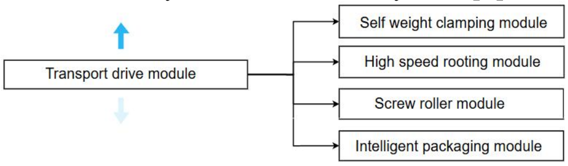

Figure 3. Functional Module Diagram

3.3 Whole Machine Workflow

The complete work flow of the equipment is as follows: manually align the root of baby cabbage with the positioning baffle downward, and place it on the clamping fixture of the loading device, and the fixture is automatically clamped by the weight of the dish; The chain drive system drives the fixture to move forward at a constant speed to transport baby vegetables to the root cutting station; The high-speed rotating disc cutter completes the root shearing, the fixture automatically loosens after running to the end, and the vegetable body contacts the spiral defoliation mechanism after falling to the lower conveyor belt; Make the outer old leaves fall off and discharge from the gap, and push the clean vegetable body into the packaging station along the designated spiral line; After the photoelectric sensor detects the material, the packaging mechanism automatically completes the film conveying and heat sealing, and finally outputs the finished product.

4. Core Mechanical Structure Design

4.1 Design of Self Weight Clamping Mechanism

The clamping mechanism is the core component to ensure the accuracy of root cutting. This design adopts the self weight profiling fixture clamping scheme without external force drive, as shown in Figure 4 below. The shape of the fixture is customized according to the average weight and maximum diameter parameters of baby cabbage. The bottom of the fixture is equipped with a pressure trigger structure, and the clamping claws on both sides are linked with the bottom pressure parts through the connecting rod mechanism. When baby cabbage is placed on the fixture, the bottom is pressed down by the gravity of the vegetable body, and the clamping claws on both sides are driven by the connecting rod drive to synchronously close to the center to complete the automatic clamping action [7,8,9]. The mechanism does not need additional cylinders, motors and other driving components, and makes full use of the characteristics of material self weight to achieve clamping, which effectively reduces the power consumption and control complexity of the whole machine. The opening of the fixture can be adjusted adaptively with the size of the dish, realizing the customized clamping of "one clip for one", adapting to different specifications of raw materials, and the clamping stability is better than that of the fixed size fixture.

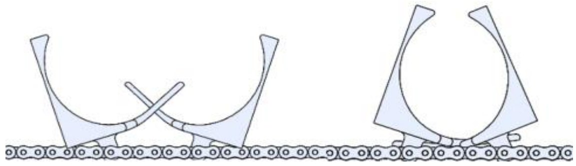

Figure4. Clamping Mechanism Loosening and Clamping State Diagram

4.2 Design of Root Removal and Spiral Defoliation Mechanism

The root removal unit adopts stainless steel disc cutter, as shown in Figure 5 below. Through the comparative analysis of three types of straight edge punching cutter, arc cutter and stainless steel disc cutter, the stainless steel disc cutter realizes rotary shearing with continuous circular blade, the cutting process is stressed evenly and runs smoothly, which can effectively avoid the damage of the dish caused by punching and tearing, and the blade is smooth and not easy to stick, which is convenient for cleaning and disinfection, so this scheme is selected [10,11]. The diameter of the cutting blade is 300mm, and the optimal cutting speed of 18m/s is guaranteed through the speed matching, and the incision is flat and smooth.

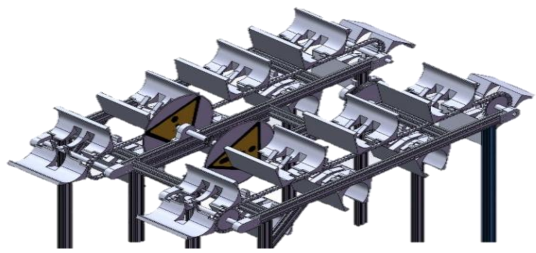

Figure 5. High Speed Root Removal Mechanism

The defoliation unit adopts a spiral stopper structure, as shown in Figure 6 below, combined with the composite defoliation principle of gravity drop impact and friction rubbing of the stopper. The root cut baby cabbage fell from the upper conveyor belt, and the outer old leaves were initially loosened by impact; Then enter the lower conveyor belt and contact the rotating screw stopper rod. During the rotation of the stopper rod, the movement of the combined conveyor belt produces continuous rubbing force on the vegetable body, making the outer old leaves completely peel off. The fallen broken leaves are discharged through the gap at the lower part of the stopper rod, and the clean vegetable body slides into the packaging station along the spiral channel. The scheme is designed according to the structural characteristics of baby cabbage "tough outside and brittle inside", which not only ensures the sufficiency of defoliation, but also avoids the rigid extrusion damage of the inner blade ball, and realizes the nondestructive defoliation processing.

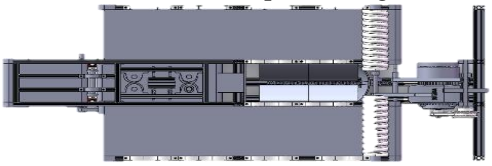

Figure 6. Leaf Shedding Mechanism of Screw Stopper

4.3 Transmission Structure Design

The transmission system is the core carrier of power transmission and process coordination of the whole machine. It undertakes the functions of speed reduction and torque increase, power split and speed matching, and is the key to ensure the collaborative operation of cutting, conveying and defoliation stations. This equipment adopts the transmission scheme of single motor centralized drive and multi branch shunt output. It takes the two-stage cylindrical gear reduction as the core, with V-belt transmission, synchronous belt transmission and chain transmission, forming a complete power transmission link, which simplifies the power structure of the whole machine while ensuring the transmission accuracy. The transmission link of the whole machine is divided into three-level deceleration and two-way output according to the function: after the power is output by the single-phase asynchronous motor, the first level deceleration is completed through the V-belt drive and input into the second level cylindrical gear reducer, and the main reduction and torque increase are realized through the two-stage gear meshing; The output end of the reducer is divided into two independent branches, which transmit power through the synchronous belt drive respectively: one is output to the cutter shaft to drive the stainless steel disc cutter to rotate at high speed, ensuring the design cutting line speed of 18m/s; The other is output to the chain drive conveying system to drive the clamping conveying line to run at a constant speed and match the overall processing beat. In this scheme, only a single motor can realize the cooperative operation of multiple mechanisms, which effectively reduces the equipment cost and control complexity.

4.4 Mechanical Structure Design of Heat Sealing Packaging

The packaging unit adopts pillow type heat sealing structure, as shown in Figure 7 below, and is composed of four executive parts, i.e. vegetable feeding baffle, film clamping mechanism, longitudinal sealing module and conveyor belt. The leafless baby cabbage falls onto the feeding baffle along the slide and is pushed forward at a uniform speed through the push stop attached to the chain; The film clamping mechanism pulls the packaging film forward synchronously to keep the same speed with the vegetable body; When the dish body completely enters the film wrapping area, the longitudinal sealing module moves up and down under the action of the crank rocker structure, and the film is cut off by the heat sealing knife to output the independently packaged finished product.

The packaging structure adopts modular design, which can adapt to the packaging requirements of different specifications of baby dishes by adjusting the width of the film and the size of the heat sealing mold. The overall structure is seamlessly connected with the front defoliation process, ensuring the continuity of the whole machine processing.

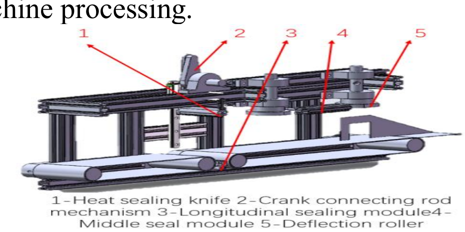

Figure 7. Intelligent Packaging Mechanism

5. Control System Scheme Design

5.1 Overall Structure of Control System

The control system is mainly designed for the packaging unit and adopts the closed-loop control architecture of "MCU+sensor+actuator" to realize the automatic operation of the packaging process. The system uses STM32 single chip microcomputer as the core control unit, collects the material feeding signal through the photoelectric sensor, and outputs the control signal to drive two stepper motors to perform the film conveying and heat sealing actions respectively, so as to realize the automatic coordination of the whole process of feed detection, film feeding and hot pressing sealing. The physical model is shown in Figure 8 below.

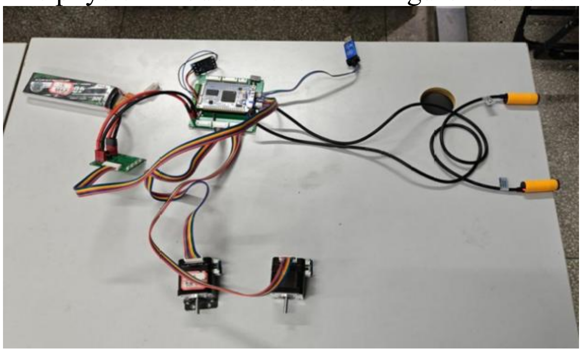

Figure 8. Physical Drawing of Control System

The control system has simple structure, high reliability, independent control for the packaging process, no interference with the mechanical transmission system, and is convenient for debugging and maintenance. The system parameters can be adjusted by single-chip microcomputer program to meet the packaging requirements of different processing beats and material specifications.

5.2 Hardware System Selection

Stm32fzgt6 single chip microcomputer is selected as the control core, and the operation ability and interface resources meet the control requirements; The detection element adopts diffuse reflection photoelectric sensor and is installed at the entrance of the packaging station to detect the feeding state of baby cabbage and trigger the subsequent packaging action; The actuator is equipped with three stepper motors, one for driving the film clamping and conveying mechanism to accurately control the film conveying length, and two for driving the reciprocating motion of the crank connecting rod mechanism to complete the heat sealing and cutting tasks of the longitudinal sealing tool and control the heat sealing duration. The power supply of the system adopts 220V mains voltage reduction scheme, which is suitable for the power supply conditions of conventional production scenes.

5.3 Automatic Control Process

The system follows the cycle control logic of "standby trigger execute reset": in standby mode, both the film conveying motor and the heat sealing motor are stopped; When the photoelectric sensor detects that baby cabbage enters the packaging station, it sends a trigger signal to the MCU; After receiving the signal, the single-chip microcomputer first starts the film conveying stepper motor to transport the corresponding length of packaging film according to the preset parameters; After the film is transported in place, the conveying motor stops, and the heat sealing stepping motor starts to drive the heat sealing tool to complete a pressing, cutting and lifting heat sealing action; After sealing, the heat sealing motor is reset, and the system returns to the standby state, waiting for the next feeding trigger. By adjusting the program parameters, the film conveying length, heat sealing time and other indicators can be flexibly modified to meet the packaging requirements of baby cabbage with different sizes, and ensure the consistency of sealing quality and packaging.

6. Calculation and Test

6.1 Matching Calculation of Power System

The equipment adopts the single motor power split scheme, which needs to calculate the power demand of the cutting branch and the transmission branch respectively, and then convert it to the motor output in combination with the transmission efficiency, and finally determine the rated parameters of the motor.

The cutting power of the tool axis is determined by the cutting force and the cutting line speed. The calculation formula of the cutting power is:

$$P1 = \frac{F\cdot V1}{1000} \quad (1)$$

Considering the fluctuation of processing conditions, the safety factor is introduced to correct the actual required power of the blade shaft:

$$P_1^{'} = k \cdot P_1 \quad (2)$$

Where: P_1 is the theoretical cutting power of the blade, kW; F is the total cutting force, N; V_1 is the cutting line speed, m/s; P_1' prime is the actual required power of the blade shaft, kW; K is the safety factor, taken as 1.3.

The transmission power of the chain drive shaft is determined by the transmission load and linear speed, and the calculation formula is:

$$P_2 = \frac{f\cdot G\cdot V_2}{1000} \quad (3)$$

The total conveying load is the total gravity of baby cabbage transported at the same time, namely:

$$G = z \cdot m \cdot g \tag{4}$$

Where: P_2 is the theoretical transmission power of chain drive, kW; F is the friction coefficient; G is the total conveying load, N; V_2 is the conveying line speed, m/s; Z is the maximum number of simultaneous conveying; M is the maximum mass of a single baby cabbage, kg; G is the acceleration of gravity, taking 9.8 m/s^2.

The total efficiency of the transmission system is the product of the efficiency of each transmission element, i. e:

$$\eta = \prod_{i=1}^{n} \eta_i \tag{5}$$

Where: η is the total efficiency of transmission branch; η_i is the single-stage efficiency of each transmission element.

After calculation, the total transmission efficiency from motor to cutter shaft η_a=0.885, and the total transmission efficiency from motor to chain drive shaft η_b=0.679. The power of each branch is converted to the motor end, and the total power demand of the whole machine is about 0.589kw. Finally, 80m2-4 single-phase asynchronous motor is selected, with a rated power of 0.75KW and a full load speed of 1390r/min, which meets the requirements of working conditions and has sufficient margin.

6.2 Check and Calculation of Transmission Components

6.2.1 V-belt drive verification

The input end adopts A-type ordinary V-belt drive, and the calculated power is determined according to the working conditions:

$$P_{ca} = K_A \cdot P \tag{6}$$

Where: P_{ca} is the calculated power, kW; K_A is the working condition coefficient, taking 1.1; P is the rated power transmitted, kW.

Belt speed is the core parameter of V-belt design, which should be controlled in a reasonable working range. The calculation formula is:

$$v = \frac{\pi d_{d1} n}{60 \times 1000} \tag{7}$$

Where: V is the belt speed, m/s; d_{d1} is the reference diameter of the small pulley, mm; n is the speed of the small pulley, r/min.

The number of V-belts shall meet the requirements of rated transmission power, and the calculation formula is:

$$z = \frac{P_{ca}}{(P_0 + \Delta P_0) K_\alpha K_L} \tag{8}$$

Where: Z is the number of V-belts; P_0 is the rated power of a single V-belt, kW; ΔP_0 is the power increment corresponding to the transmission ratio, kW; K_α is the wrap angle coefficient; K_L is the belt length coefficient.

The axial force is the reference for the design of shafting and bearing, and the calculation formula is:

$$F_Q = 2 z F_0 \sin\frac{\alpha_1}{2} \tag{9}$$

Where: F_Q is the axial force, N; F_0 is the initial tension of a single belt, N; α_1 is the wrap angle of the small belt pulley.

After calculation, the belt speed is 5.82m/s, which is in the reasonable working range of 5~25m/s; Two A-type V-belts are selected, and the wrap angle, initial tension and axial force meet the design requirements.

6.2.2 Gear transmission strength check

The high-speed gear transmission is designed according to the tooth surface contact fatigue strength, and the core design formula is:

$$d_{1t} \geq \sqrt[3]{\frac{2K_{Ht}T}{\phi_d} \cdot \frac{u+1}{u} \left(\frac{Z_H Z_E Z_\varepsilon}{[\sigma_H]}\right)^2} \tag{10}$$

Where: d_{1t} is the diameter of the indexing circle of the trial pinion, mm; K_{Ht} is the trial load factor; T is the torque transmitted by the pinion, N·mm; ϕ_d is the tooth width coefficient; u is the tooth ratio; Z_H is the regional coefficient; Z_E is the material elastic influence coefficient, $\sqrt{\text{MPa}}$; Z_ε is the coincidence coefficient; $[\sigma_H]$ is the allowable contact stress, MPa.

Check according to the bending fatigue strength of the tooth root, and the core formula is:

$$m \geq \sqrt[3]{\frac{2KTY_\varepsilon}{\phi_d z_1^2} \cdot \frac{Y_{Fa} Y_{Sa}}{[\sigma_F]}} \tag{11}$$

Where: m is the gear modulus, mm; Y_ε is the bending coincidence coefficient; z_1 is the number of pinion teeth; Y_{Fa} is the tooth profile coefficient; Y_{Sa} is the stress correction factor; $[\sigma_F]$ is the allowable bending stress, Mpa.

The number of small gear teeth z_1 =24, the number of large gear teeth z_2=82, modulus M=1 mm, and the materials are 40Cr quenched and tempered and 45 steel quenched and tempered respectively. After verification, the tooth surface contact stress and tooth root bending stress are less than the allowable value, and the gear strength meets the long-term working requirements.

6.3 Shaft System Strength Check Calculation

The strength of high-speed shaft, intermediate shaft and low-speed shaft is checked by bending torsion synthetic strength method. The shaft material is 40Cr quenched and tempered.

The bending section coefficient and torsional section coefficient of the shaft are respectively:

$$W = \frac{\pi d^3}{32} \tag{12}$$

$$W_T = \frac{\pi d^3}{16} \tag{13}$$

Where: W is the bending section coefficient, mm^3; W_T is the torsional section coefficient, mm^3; d is the shaft diameter of dangerous section, mm.

For the shaft with unidirectional transmission, the torque is treated as a pulsating cycle, and the reduction coefficient α=0.6 is introduced. The formula for calculating the equivalent stress of bending and torsion is:

$$\sigma_{ca} = \sqrt{\sigma^2 + 4(\alpha\tau)^2} \tag{14}$$

The bending normal stress and torsional shear stress are respectively:

$$\sigma = \frac{M}{W}, \quad \tau = \frac{T}{W_T} \tag{15}$$

Where: σ_{ca} is the equivalent stress, MPa; σ is bending normal stress, MPa; τ is torsional shear stress, MPa; α is the torque conversion coefficient; M is the composite bending moment of the dangerous section, N·mm; T is dangerous section torque, N·mm.

Taking the dangerous section of high-speed shaft as an example, the equivalent stress is calculated to be about 15.12mpa; Similarly, the maximum equivalent stress of the intermediate shaft is 11.52mpa, and the maximum equivalent stress of the low-speed shaft is 6.89mpa, which are far less than the allowable bending stress of 70MPa, and the strength of the shaft system meets the design requirements.

6.4 Equipment Performance Analysis

From the perspective of theoretical performance, the equipment can realize the whole process of automatic processing of baby cabbage from raw materials to finished products. The single channel operation can replace 2-3 workers, and the production efficiency is more than double that of the traditional manual mode, effectively reducing the labor cost of enterprises. At the same time, mechanized processing has greatly improved the degree of product standardization, with consistent root cutting length, uniform defoliation, regular packaging and sealing, and significantly improved the commerciality of finished products. The equipment has compact structure and controllable cost, which is suitable for the production needs of small and medium-sized vegetable processing enterprises, and has high popularization and application value.

7. Summary and Outlook

In view of the industry pain points of baby vegetable, such as low efficiency of postpartum manual processing, poor standardization and easy damage to the vegetable body, this paper designs a clean processing machine for baby vegetable, which integrates root removal, leaf removal and packaging. By analyzing the physical characteristics and processing requirements of baby cabbage, the overall scheme design of the whole machine was completed, and the four core mechanisms of clamping, root cutting and defoliation, conveying and packaging were designed in detail. The automatic packaging control system based on STM32 was built, and the mechanical reliability of the equipment was verified through dynamic force calculation, transmission check and shaft bending and torsion strength formula.

The core innovation of the equipment is reflected in three aspects: first, the self-adaptive clamping mechanism is adopted, which can realize stable clamping without additional drive, with simple structure and strong material adaptability; The second is to adopt the gravity drop and spiral kneading compound defoliation scheme, which takes into account the defoliation efficiency and the integrity of the dish, and solves the problem that the traditional mechanism is easy to damage the leaf ball; Third, the whole machine adopts a symmetrical three-dimensional compact layout, with high space utilization and controllable manufacturing cost. The equipment fills the technical gap of the domestic baby vegetable integrated processing equipment, and has important practical value in promoting the mechanization upgrading of leaf vegetable processing industry and assisting the Rural Revitalization.

The follow-up research can further introduce the automatic feeding mechanism and machine vision detection module to realize the automatic feeding and online sorting and grading of baby cabbage quality; At the same time, optimize the integrated design of cleaning function and defoliation mechanism, expand the functional boundary of the equipment, improve the intelligent level of the whole machine, and provide more perfect technical solutions for the upgrading of leaf vegetables postpartum processing equipment.

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