IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676, p-ISSN: 2320-3331, Volume 19, Issue 1 Ser. 1 (Jan. – Feb. 2024), PP 19-26
www.iosrjournals.org

Design and test of potato slicer control system with dynamic adjustment of feeding speed

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Abstract:
Aiming at the problems of poor cutting quality, high breakage rate and low automation degree of potato slicer, a control system suitable for dynamic adjustment of potato feeding speed was developed. The system uses laser sensor and feed shunt device to detect feed speed, PLC to control feed speed, improve feed uniformity and cutting stability. At the same time, the hardware and software of the system are designed and tested. The test results show that the feed speed dynamic adjustment system can meet the qualified rate and efficiency of potato slicer in production, and the qualified rate of potato slicer is > 92%, which greatly improves the cutting quality and efficiency of potato slicer in the production line.

Key word: *Cutting machine, control system, PLC, Design and test*

Date of Submission: 01-01-2024 Date of acceptance: 11-01-2024

I. Introduction

Potato is the world's fourth largest crop after wheat, corn and rice, and China's potato planting area and total output ranks first in the world. In the field of food processing, potato chips as a popular snack and food ingredients, the efficiency and quality of its production process has become the focus of attention of producers and researchers. In order to meet the growing market demand for potato chips, potato slicer, as an efficient and fast processing equipment, has become an important link in the processing of potato chips. Although China began to independently develop relevant potato slicing technology and equipment in 1998, most of the equipment is mainly imported. At present, the domestic research on potato slicing machinery has made some progress, but due to the weak research foundation and conditions, the research results are difficult to meet the needs of the industry, and most of the potato slicing machines developed are less automated than manual, with high labor and time costs and low processing efficiency. In this paper, the potato cutting machine is designed to distribute the potatoes. A single point laser sensor is used to detect the feeding amount of potatoes in real time, and the feeding speed is adjusted by controlling the quantity of potatoes transported per unit time, so as to achieve the matching of feeding speed and cutting speed, so as to improve the cutting quality and cutting efficiency. This paper provides reference for structural optimization of potato slicer.

II. The overall structure and working principle of the cutting machine

System composition

The potato slicer with dynamically adjustable feeding speed includes feeding diverter, centrifugal drum, slicing knife, slicing thickness adjusting device, slicing device, knife changer, frame, power transmission and PLC control system and so on. Among them, the feeding diversion device consists of conveyor belt, diversion device and single-point laser sensor, etc.; centrifugal drum consists of fixed outer cylinder, rotating inner cylinder and pushing material blade; slicing thickness adjusting device is the slicing thickness adjusting arc through the pin and the fixed outer cylinder connection and become; cutting device consists of cutting blade, spacer and cutting knife shaft; knife changing device is the cutting knife shaft mounted on the eccentric shaft through the eccentric shaft rotation to achieve the purpose of convenient knife changing; power transmission device, power transmission device and PLC control system. Convenient to change the knife; power transmission system consists of gear motor, pulley, gear, double sprocket, V-belt and chain, PLC control system consists of PLC controller, speed sensors, single-point laser sensors, frequency converter and so on. Among them, the knife, transmission system and motor are protected at the shell, in order to facilitate the display of the internal structure of the figure is not shown, feeding and cutting speed dynamically adjusted potato cutting machine test bench structure shown in Figure 1 .

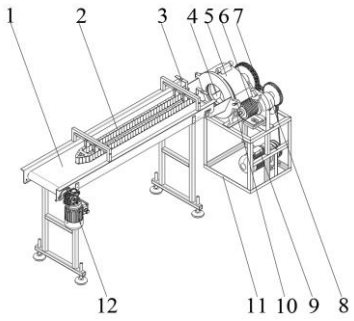

Fig.1 Structure diagram of potato slicer test bench with dynamic adjustment of feeding speed

1. Conveyor belt 2.Diverter device 3.Single point laser sensor 4.Centrifugal roller 5.Slicing thickness adjusting arc plate 6. Strip cutter 7. Transmission device 8. Knife change device 9. Strip cutter motor 10. Slicing knife 11. Frame 12.Conveyor belt motor

Principle of operation

The potato cutting machine described herein mainly adopts a combination of a rotational speed sensor and a laser sensor to achieve the purpose of detecting the amount of potato feeding and adjusting the feeding speed. Potato Strip Cutting Machine with Dynamic Adjustment of Feeding Speed Before cutting the stripes, firstly, the size of the cut potato stripes is adjusted according to the scale on the thickness adjusting device, and different sizes of strip cutting knives can be installed. The specific workflow is as follows: potatoes are conveyed from the front-end equipment of the assembly line to the feeding diversion device, the rotational speed sensor recognizes the centrifugal drum and the conveyor belt motor rotational speed, and the conveyor belt motor rotational speed is automatically set by recognizing the centrifugal drum rotational speed of the strip cutter. Reduction motor drive conveyor belt operation, diversion detection device will be arranged to transport potatoes to the centrifugal drum, laser sensor detection of the number of potato feeding, through the centrifugal drum rotating close to the inner wall of the drum to do the circular motion, when the potato rotates to the slicing knife installation position when the chip is cut into slices, potato chips rely on the inertia of continuing to move

forward by the rotating strip cutter cutting for the stripe, to complete the entire strip-cutting process. The feeding speed of potato is regulated by PLC controller, the laser sensor installed at the back of the shunt detection device detects the quantity of potato, and the PLC calculates the quantity of potato fed per unit of time and compares it with the range of the quantity of potato set in advance to judge whether the feeding speed is increasing or decreasing.

III. Design of the control system

Control hardware design

The control system is mainly composed of feeding speed control module, cutting speed control module, detection module and display module. The main task of the feeding speed control module is to regulate and control the feeding speed of potato to ensure the stability of the feeding quantity; the main task of the cutting speed control module is to regulate and control the centrifugal drum speed of the strip cutter, which is convenient to regulate the cutting speed; the main role of the detection module is to detect the number of potatoes entering the centrifugal drum, the centrifugal drum speed and the speed of the feeding diversion device in a unit of time to provide data for the regulation module; the main task of the display module is to display all aspects of the data of the strip cutter to realize the feeding of the strip cutter, and so on. The main role of the detection module is to detect the number of potatoes entering the centrifugal drum in a unit time and the speed of the feeding diversion device, and to provide data for the adjustment module; the main task of the display module is to display the data of the cutting machine in all aspects, realize the automation of the cutting machine and the safety warning function, and facilitate to improve the efficiency of the display of the fault point, and to ensure that the work of the cutting machine is carried out safely and orderly.

The control system hardware mainly consists of control box, three-color indicator, PLC controller, touch screen, feeding device manual speed adjustment knob, centrifugal drum manual speed adjustment knob, emergency stop switches, speed sensors, laser sensors, digital-to-analog converter, frequency converter. The system drives the normal operation of each module through logic control to ensure the stability of the feeding speed adjustment line. Its PLC basic wiring diagram shown in Figure 2

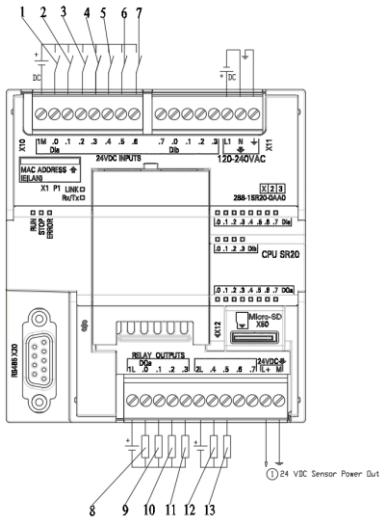

Fig.2 PLC Basic Wiring Diagram

1. Start button 2. Emergency stop switch 3. Centrifugal drum manual speed knob 4. Conveyor belt manual speed button 5. Speed sensor 6. Laser sensor 7. Touch screen input 8. Conveyor motor rotation 9. Strip cutter motor rotation 10. Conveyor motor speed control 11. Strip cutter motor speed control

12.Warning light 13.Touch screen output

Control system software design

In this paper, the potato cutter detection device with dynamic adjustment of feeding speed adopts the combination of speed sensor and laser sensor to regulate and control the feeding speed of potato, the speed sensor detects the speed of centrifugal drum and conveyor motor of the cutter, and the single-point laser sensor detects the number of potato falling into the centrifugal drum in unit time; the PLC controller calculates the initial speed of conveyor motor based on the speed of centrifugal drum and makes real-time adjustment based on the number of potato falling into the centrifugal drum detected by the laser sensor, which is compared with the theoretically set potato feeding quantity. The PLC controller calculates the initial speed of the conveyor belt motor according to the rotational speed of the centrifugal drum and adjusts the speed in real time based on the number of potatoes falling into the centrifugal drum per unit of time detected by the laser sensor, compares the potato feeding volume with the theoretically set potato feeding volume, and then adjusts and controls the speed of the conveyor belt in real time, so as to improve the efficiency of the strip-cutting machine and reduce the phenomenon of the pile-up of materials in the centrifugal drum due to the excessively large amount of material feeding.

Potato diversion control logic

As the number of potatoes conveyed on the assembly line is not uniform, there will be too much feed leading to a decline in cutting quality, and even the cutter can not run normally. In order to solve this problem, this paper uses a single point laser sensor to fall into the centrifugal drum within a unit of time in the number of potato detection[23] , PLC controller to the laser sensor to obtain the number of potato information for the operation and comparison with the set value, so as to determine the feeding diversion device conveyor belt speed increases or decreases, when falling into the centrifugal drum within a unit of time in the number of potato is greater than the set value, the conveyor belt speed decreases to prevent the accumulation of material in the centrifugal drum, when falling into the centrifugal drum within a unit of time, the conveyor belt speed decreases to prevent the accumulation of material. When the number of potatoes falling into the centrifugal drum within a unit of time is greater than the set value, the conveyor belt speed decreases to prevent the centrifugal drum from generating material accumulation, and when the number of potatoes falling into the centrifugal drum within a unit of time is less than the set value, the conveyor belt speed increases, so that the feeding speed is constant, and the effect of cutting stripes is stable. The control flow chart of feeding speed adjustment is shown in Figure 3.

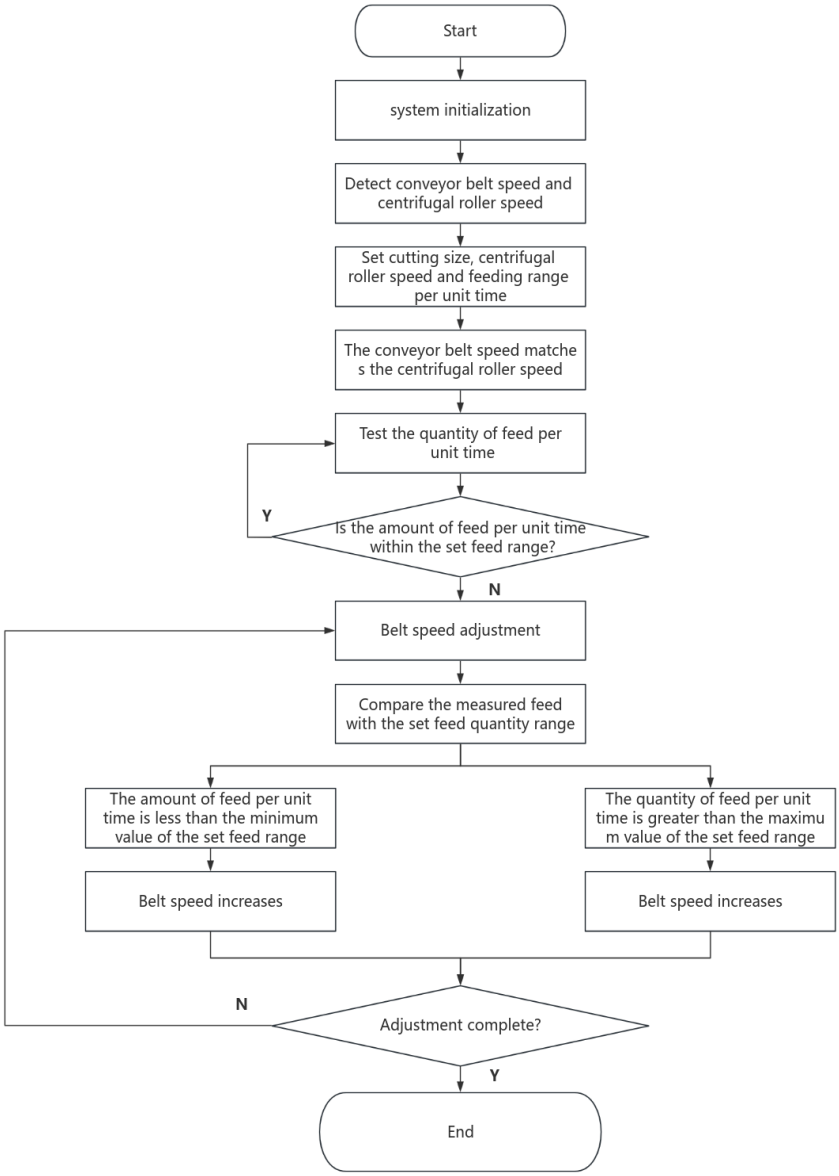

Figure 3 Control flow chart

Conveyor Belt Speed Analysis for Diversionary Inflow Devices

Potato feeding speed and cutting speed match is the key to potato feeding speed regulation, because the potato cutting machine in the assembly line when the feeding speed is faster, so in the speed adjustment process should leave a certain margin to avoid too late to feed speed adjustment lead to the centrifugal drum in the accumulation of materials, potato feeding volume and cutting volume to meet the following relationship:

$$\begin{cases} Q_q = \dfrac{nZ\delta t}{60h_a} \\ Q_s = \dfrac{1000vt}{2l_a} \\ 0.9Q_q \le Q_s \le 0.95Q_q \end{cases} \quad (1)$$

Where Qq - theoretical potato cutting capacity, pcs; Qs - Potato feed setpoint, pcs; n-centrifugal drum speed, r/min; δ-slice thickness, mm; Z-Number of pusher blades; v-conveyor belt speed;

The initial speed of the conveyor belt should be satisfied from Eq. 3:

$$v = \frac{nZ\delta l_a}{30000h_a} \times 0.95 \quad (2)$$

On this basis through the PLC than the laser sensor detection data and potato feeding volume set number of comparison, real-time speed regulation of the conveyor belt.

IV. Potato cutter control performance test and analysis

This experiment selects the qualified rate of potato cutting strips and the efficiency of cutting strips as the evaluation index, according to the current market potato cutting machine work, set the rotational speed of the centrifugal drum of the potato cutting machine as 150r/min, 200r/min, 250r/min to carry out the experiment, and the speed adjustment range of the feeding diversion device is 0.3m/s~0.5m/s to carry out five repetitions of the test, statistics Potato slitting machine's slitting qualification rate η_1 , slitting breakage rate η_2 and slitting efficiency η_3 .

Cutting pass rate η_1 refers to the number of passing fries in the cut fries as a percentage of the total number of fries measured i.e.

$$\eta_1 = \frac{Q_h}{Q_z} \times 100\% \quad (4)$$

Where Q_h - number of qualified fries in the sample, pcs.

Q_z - total number of measured samples, pcs.

Split Crush Rate η_2 means that the cut fries are sorted into intact samples and broken (fractured, damaged) samples for weighing, and the percentage of the ratio of the mass of the broken samples to the mass of the broken samples plus the intact samples is the Split Crush Rate

$$\eta_2 = \frac{P_s}{P_s + P_w} \times 100\% \quad (5)$$

Where P_s - mass of broken sample, g

P_w - mass of intact sample, g

Cutting efficiency η3 refers to the weight of potatoes cut by the potato cutter per unit time, and the test results are shown in the following table.

test results

Centrifugal drum speed r/min	Test number	η_1 (%)	η_2 (%)	η_3 (kg/h)
150	1	94.21	3.21	1639
	2	94.28	3.42	1742
	3	93.12	2.61	1674
	4	93.46	2.75	1653
	5	93.71	2.68	1623
200	1	96.29	1.62	2375
	2	96.22	1.74	2492
	3	96.31	1.69	2467
	4	96.54	1.55	2334
	5	96.46	1.57	2469
250	1	93.83	2.95	3155
	2	92.91	3.66	3216
	3	93.52	1.57	3268
	4	93.21	1.55	3194
	5	94.72	3.41	3174

The above cutting experiment verifies that the strip cutter maintains normal operation under this control system, and combined with the above results, it can be seen that under the condition of the same rotational speed of the centrifugal drum, the efficiency and quality of the potato cutting machine are more stable, and there is a smaller deviation, so it shows that the system is able to meet the cutting requirements of the potato cutting machine.

V. Conclusion

(1) Designed a potato cutting machine feeding speed dynamic adjustment system control system, at the same time carried out the design of the relevant hardware and software, through the corresponding logic sequence to realize the stable operation of the cutting machine in the assembly line and speed regulation, the use of PLC control of conveyor belt speed adjustment, to achieve the stability of the potato feeding to improve production efficiency.

(2) Potato cutting machine assembly line test shows: feeding speed dynamically adjusted potato cutting machine in the assembly line when the work of cutting stripes qualified rate> 92%, to meet the production requirements of potato cutting machine, improve the automation of equipment.

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