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Potato bagging machine control system design and test

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Abstract:
For the existing potato bagging machine in China, there are problems of qualified weighing rate, low bagging efficiency and high labor cost, we developed a high-efficiency flow quantitative bagging control system which is applicable to potato flow quantitative bagging machine. The control system is based on Siemens PLC S7-200, using cylinders as the actuating element, using the principle of S-type tensile force sensor weighing, through the relevant logic sequence control solenoid valve on and off to achieve the actuating cylinder action, so that each station can selectively work at the same time or work individually, improving the flexibility of bagging and bagging efficiency, and through the relevant sensor to collect information to determine the action of each actuator in place, improving the work accuracy and intelligence. The accuracy and intelligence of the work are improved. At the same time, the software and hardware design of the split quantitative bagging control system is carried out, and bagging performance tests are conducted. The verification tests show that the potato split quantitative bagging control system meets the design requirements of high weighing qualification rate, and the weighing qualification rate is ≤ 2%, which can better realize quantitative potato bagging. This study provides a certain reference for improving the automation of potato bagging machine and for the subsequent research on the whole process of potato mechanization.

Key word: *Bagging machine, control system,PLC,design and experiment*

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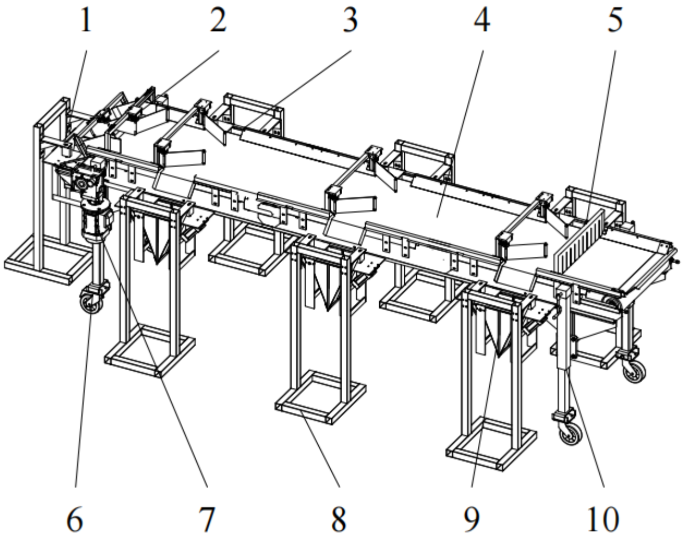
I. introduction

Potatoes can be used not only as a grain reserve, but also as a vegetable fresh food, and processing purposes are very wide, and thus have an important role in the industry. As potatoes have become the fourth largest food crop, their acreage and total output have continued to increase, but due to the late and slow development of full potato mechanization in China,[1-2] the mechanization level is lower than in developed agricultural countries, and research on potato bagging machines is relatively scarce, and with the intensification of the Industry 3.0 era, research on potato triage and quantitative bagging should be given more attention. Bagging as a key step after the potato harvest, for its transport storage, and sales to provide a convenient, to meet the growing demand for potato planting, harvesting and transport storage, etc., should increase the research and application of potato machinery. At present, China's potato bagging machinery is less, part of the bagging machinery has been developed as part of the combined harvester, but there is poor adaptability and low bagging efficiency, the overall price is expensive and other problems; part of the bagging machinery is developed as a stand-alone bagging machine, but the bagging process is dependent on manual, costly labor and time costs, low bagging efficiency and bagging quality is not standardized and other problems.In view of the above problems, this paper designs a control system applicable to potato bagging machine[3-4] . The system has the features of full and semi-automatic selection of multi-station bagging, accurate quantitative and stable bagging, efficient intelligent display and high efficiency of bagging and changing, safety and timely warning and alarm, etc[5-10] . It can improve the automation level of potato bagging machine to a certain extent and reduce the problems of over-reliance on manual labor, low bagging efficiency and inconsistent quality of common bagging machine.

II. Overall structure and working principle of bagging machine

2.1 Overall Structure

Potato bagging machine mainly consists of fixing device, diversion device, diversion device, quantitative bagging device, conveying device, detection device, control device and so on. The fixed device is composed of adjustable support frame and frame; the diversion device is composed of rotating cylinder, rotating shaft and rotating baffle; the diversion device is composed of angle adjustable diversion plate and left and right side baffle; the quantitative bagging device is composed of clamping cylinder, rotating shaft, opening and closing plate and bearing; the conveying device is composed of frequency converter, reducer motor and conveyor belt; the detecting device is composed of magnetic switch, speed detecting The testing device is composed of magnetic switch, speed sensor, S-type tension sensor and signal transmitter, etc.; the control device is composed of Siemens PLC S7-200, expansion module EM235 and rotary button, touch screen, etc. The bagging machine is equipped with 7 bagging stations, 3 on the left and right side and 1 at the end, of which 6 on the left and right side are automatically selected for bagging according to the actual working conditions in the control system, and its structure sketch is shown in Figure 1.



1. gravity sensor 2. tail diversion device 3. diversion device 4. conveying line 5. potato stopping device 6. universal wheel 7. speed reducing motor 8. weighing fixed bracket 9. quantitative bagging device 10. retractable frame

Figure 1 Potato bagging machine structure schematic diagram

2.2 Overall Structure

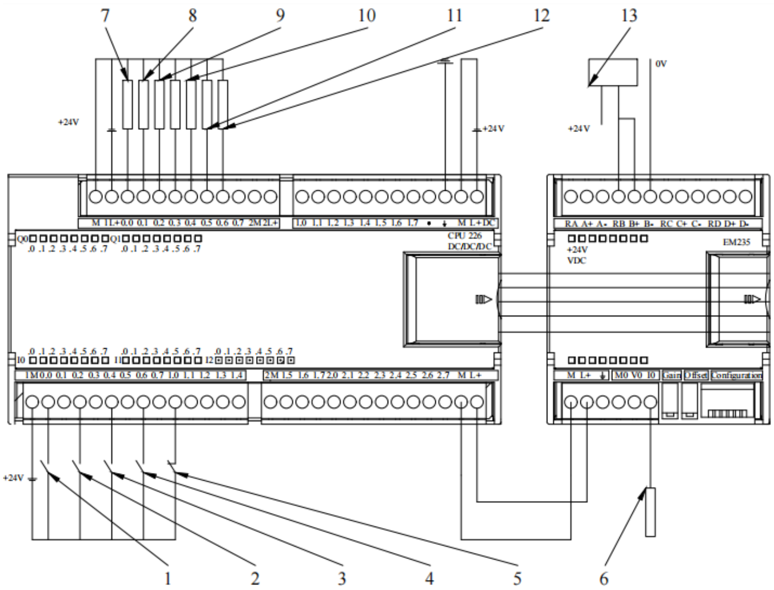
In this paper, the potato bagging machine detection device adopts the combination of S-type tension sensor and signal transmitter to improve the bagging weighing accuracy and stability; the shunting device selects the rotary cylinder as the main actuating element of the shunting device, using the single reciprocal rotary motion of the rotary cylinder to simplify the action of the shunting bin door and improve the efficiency of the bin door shunting; the bagging device selects the one-way cylinder as the main actuating element to drive the action of the bagging and changing mechanism The bagging device uses one-way cylinder as the main actuating element to drive the bagging and changing mechanism to realize the efficient bagging and changing, which can better reduce the collision damage of potato into the bag. Potato shunting quantitative bagging machine in the work, bagging side of the station control principle: the transport device will transport potatoes to the required bagging side of the station before the shunting device shunting treatment of potatoes into the diversion device slide into the quantitative bagging device clamping nylon bags, at this time S-type tension sensor real-time detection of the quality of potatoes in the bag, when the potatoes in the bag reaches the set bagging quality, PLC control the bagging side of the station shunting Device at the two-position five-way solenoid valve power off, that is, control the rotary cylinder rotation reset shunt stop, control the bagging side of the station quantitative bagging device two-position five-way solenoid valve power, that is, control the clamping cylinder forward stretch loose bag, to reach the set quality of potato bags can be removed, after a good bag to repeat the above control action.

Bagging tail station control principle: potatoes transported by the conveyor to the end of the diversion device, after the diversion into the tail quantitative bagging device clamping bag, when the potatoes in the bag reaches the set bagging quality, PLC control inverter parameters, making the reducer motor deceleration to a certain speed, control the tail quantitative bagging device at the two-position five-way solenoid valve is energized, that is, to control the clamping cylinder forward to loosen the bag, to reach the set quality of potato bags can be removed. Quality of potato bags can be removed, to be replaced after the bag, PLC control the two-position five-way solenoid valve power off, that is, to control the clamping cylinder reset the bag, control the speed of the reducer motor to set speed, repeat the above tail bagging station bagging action.

III. Control system design

3.1 Control system hardware design

The control system hardware mainly consists of control base box, three-color indicator, main controller, touch screen, switch knob, emergency stop switch, speed sensor, S-type pull sensor, transmitter, inverter, solenoid valve, etc. The system controls the normal operation of the actuating elements through certain logic to ensure the accuracy of the quantitative weighing of the bagging station, the control system in the base box is based on Siemens PLC S7-200CN. The selected CPU model is 226 CN[11-12] , with 24 input terminals and 16 output terminals, meanwhile, to ensure the accurate conversion and identification of digital and analog quantities of the weighing signal, on the basis of the selected S-type tension sensor, the DY510 signal transmitter is selected, which has the functions of internal voltage stabilization, constant current supply bridge, linear compensation, etc., so as to ensure the stable measurement of potatoes; the EM235 digital-to-analog conversion The EM235 digital-to-analog converter module is used to convert the analog signal output from the signal transmitter into a digital signal, which is then transmitted to the PLC for calculation and related control; the touch screen is selected from the Kunlun TPC7032Kx, a four-wire resistive type, with a working voltage of 24V; the AC contactor is selected from the model NXC-12, with a coil voltage of AC220V; the circuit breaker is selected from the model NXBLE-63, with the number of stages 4P, and the rated current is 25A; the two-position circuit breaker is selected from the model NXBLE-63, with the number of stages 4P. The model number of the circuit breaker is NXBLE-63 with 4P and 25A rated current; the model number of the two-position five-way solenoid valve is 4V210-08 with DC24V working voltage; the model number of the switching power supply is S-120-24 with 10A and 24V output current and voltage, which can meet the working voltage requirements of the relevant components. the wiring diagram of the PLC and the expansion module is shown in Figure 2 below.



1.start knob 2. work station Ⅰcylinder loose bag knob 3. work station Ⅰcylinder clamping bag knob 4. work station Ⅰrotary cylinder shunt knob 5. three color indicator 6. touch screen 7. work station Ⅰbag filling solenoid valve work 8. work station Ⅰrotary solenoid valve work 9. work station Ⅶtail solenoid valve work 10. frequency converter work 11. High speed operation of gear motor 12. Low speed operation of gear motor 13. Signal transmitter

Figure 2 PLC and expansion module part wiring diagram

In the conveying device, the power source is GPG geared motor with rated power of 0.75KW, the inverter is ABG multi-functional vector type, model 0.72G-A3, which is suitable for the above geared motor, and the speed measurement is OMRON E6B2-CWZ6C incremental encoder, which has the characteristics of high measurement accuracy and stable measurement. 10A rotating cylinder, two angle bolts can be adjusted to change the swing angle of the rotating cylinder, plus the magnetic switch Q-A93 to detect the cylinder in place; the bagging device uses model SC50*75-S cylinder, plus the CS1-U magnetic switch; the detection device uses model LY-104 S tension sensor, plus the DY-510 signal transmitter, which has the advantages of output The output analog signal is stable, and the measurement accuracy is high.

3.2 Control system software design

3.2.1 Conveyor module design

The control principle of conveyor control module: PLC controls the inverter according to the actual working condition, and then controls the speed of the gear motor by changing the relevant frequency value. The ABG multi-functional vector inverter adopts PWM frequency modulation, i.e. pulse width modulation, which is characterized by high efficiency, no additional loss in the speed regulation process and large speed range, good mechanical characteristics and high control accuracy. Its conveying speed control formula is

As in any short collision process, compared with the huge internal force between the colliding objects, the impulse of the external force is insignificant, so it can be considered that the total momentum of the system in the collision process is conserved. As the fall of potatoes and the bag of stationary potatoes collision time is very short, and the collision process generally have mechanical energy loss, the collision between potatoes and potatoes belong to the recovery coefficient of 0 to 1 incompletely elastic collision, the collision process momentum theorem is

$$n_1 = 60\frac{f}{p} \qquad (1)$$

Where: n_1 is the speed of the geared motor, r/min; f is the frequency, Hz; p is the number of pairs of magnetic poles of the geared motor.

When the tail bagging station reaches the set bagging quality, the control center will control the conveyor belt speed to reduce to a certain value after judging, and then control the conveyor belt speed to return to the original set value after the bags are changed again.

3.2.2 Diversion bagging control module design

In order to improve bagging efficiency and reduce energy losses, the control system according to the total amount of potatoes to be bagged intelligent selection of shunt bagging station. Control principle: the first shunt bagging as shown in Figure 5, the control system control bagging at two five-way solenoid valve does not work, that is, the potato bag placed at the bagging device, then the clamping bag cylinder began to work to clamping the potato bag, control shunt at two five-way solenoid valve work, that is, the rotary cylinder began to work on the conveyor belt potato shunt to the bagging device. When the potatoes in the bag reach the set bagging quality, the control system first control the shunt two five-way solenoid valve does not work, that is, the rotary cylinder reset, then stop the shunt, and then control the bagging two five-way solenoid valve work, that is, the clamping cylinder forward to loosen the bag, the potato bag can be taken off.

3.2.3 Detection module design

The detection module includes quality detection and speed detection. The quality detection adopts the combination of S-type tension sensor and signal transmitter. Quality detection principle: S-type tension sensor measures the total weight of the bagged potatoes, and the measured electrical signal is converted into a digital signal by the signal transmitter and delivered to the expansion module, which is converted into an analog signal by the expansion module and finally judged by the PLC S7-200 whether the set bagged weight is reached.

As the effect of the zeroing of the transmitter will affect the detection error of the potato quality, it is necessary to calibrate the zero point of the S-type pull sensor in the absence of any load, in the weighing state, adjust the size of the signal gain, so as to improve the quality measurement, that is, in the no-load state after the installation of the S-type pull sensor, the zero potentiometer is adjusted to 4mA, after loading the weight M_1 to maintain stability, use the multimeter current gear to measure the output Current position, adjusted to I.Its signal gain adjustment formula is

$$I = \frac{M_1}{M_2} \times 20 + 4 \qquad (2)$$

Where:I is the gain output current, mA; M_1 is the known object weight, Kg; M_2 is the total range of S-type tension sensor.

After zeroing, the electrical signal of the mass measured by the S-type pull sensor is input to the signal transmitter, and this electrical signal is converted into 4-20mA current value and output to the analog input register of the expansion module, which is converted to get the actual measured potato mass of the S-type pull sensor after a certain formula of PLC. Its bagging quality detection formula is

$$G = M_2 \frac{(AIW0-6400)}{(32000-6400)} \qquad (3)$$

Where:G is the mass of potatoes in bags, Kg; $AIW0$ is the analog input register position.

The signal transmitter selects the current output mode, i.e. when the input current value is 4mA, the corresponding output analog value is 6400, when the input current value is 20mA, the corresponding output analog value is 32000. i.e. the conversion principle is: when the S-type tension sensor measures the electrical signal of the mass, after the mass detection formula is transformed, the analog signal is output to the VD506 channel for storage, and then after the digital signal is transformed and delivered to the VD500 channel for real-time display on the touch screen. The digital signal is transformed and delivered to VD500 channel for real-time display on the touch screen.

After the above formula conversion can be obtained after the actual bagged potato gravity value G, its PLC conversion program as shown in Figure 3.

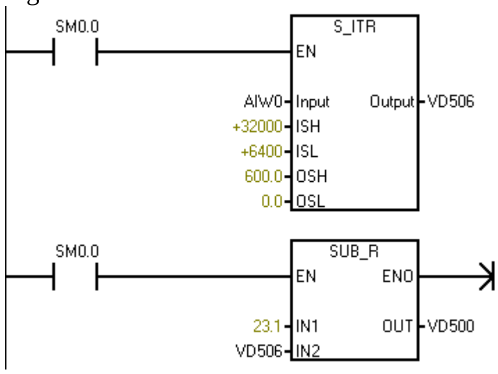


Figure 3 PLC program quality conversion chart

The speed detection is measured by OMRON E6B2-CWZ6C incremental encoder. The measurement principle is that the encoder is installed on the shaft of the geared motor, the controller is used to count the encoder, and finally the conveying speed of the geared motor is obtained according to the number of pulses measured in a fixed time. Its speed detection calculation formula is as follows

$$n_2 = \frac{M_3}{C \times T_0} \quad (4)$$

Where:n_2 is the actual speed of the geared motor measured by the encoder, Kg; M_3 is the total number of pulses obtained from the encoder, pcs; C is the total number of pulses in a single turn of the coder, pcs; T_0 is the measurement time, s.

IV. Potato bagging machine control performance test and analysis

The test selection of potato weighing qualified rate as an evaluation index, based on the current market bagging potato specifications selected single bag 40kg as the standard bagging quality, bagging quality error standard range within 5% that is qualified bagging, the choice of nylon bag specifications for 1000 × 700mm, bagging test program designed to test the accuracy of the quantitative control system. Bagging test quality of 30, 40, 50kg, bagging station selection side station Ⅰ, the diversion angle is set to 45 °, the conveyor belt speed is set to 0.44m / s, on the basis of 7 stations per standard bagging repeat 5 times test, calculate and statistical weighing error rate η_0; weighing qualification rate evaluation criteria are: after the completion of bagging at a single station, with Electronic scale to review the potato bagging quality and compare with the standard quality, when the quality error within 5%, that is, the bag as qualified bags, by counting the number of qualified bags S_1 and the percentage value of the total number of bags S_0, and finally get the weighing qualification rate η_1, the above evaluation index expression is

$$\begin{cases} \eta_0 = \dfrac{|m_1 - m_0|}{m_0} \times 100\% \\ \eta_1 = \dfrac{S_1}{S_0} \times 100\% \end{cases} \quad (5)$$

Where:η_0 is the weighing error rate, %; η_1 is the weighing pass rate, %; m_0 is the set bagging mass of potato, kg; m_1 is the set bagging mass of potato, kg; S_0 is the total number of bags of potato, one; S_1 is the number of qualified bags of potato, number.

The test results are shown in the following table.

Table 1 Control test results

Bagging quality/kg	Workstation serial number	Weighing error rate η_0/%					Number of qualified bagging bags S_1/number	Weighing qualification rate η_1/%
30	Ⅰ	4.14	3.15	3.81	3.21	4.03	5	94.29%
	Ⅱ	4.15	4.67	4.36	3.87	3.54	5	
	Ⅲ	3.39	2.78	3.21	1.28	2.43	5	
	Ⅳ	2.22	2.36	1.11	1.32	1.67	5	
	Ⅴ	4.35	4.78	6.85	3.92	4.58	4	
	Ⅵ	4.57	3.23	4.46	3.69	4.32	5	
	Ⅶ	3.23	4.28	5.81	4.02	3.86	4	
40	Ⅰ	3.37	1.23	4.48	2.82	5.06	4	97.14%
	Ⅱ	2.81	1.28	3.18	2.57	4.32	5	
	Ⅲ	3.36	2.36	3.96	4.25	3.68	5	
	Ⅳ	3.21	2.41	3.84	2.98	3.37	5	
	Ⅴ	1.11	0.96	3.43	3.56	2.63	5	
	Ⅵ	2.85	2.68	4.19	3.05	2.51	5	
	Ⅶ	4.46	1.98	2.99	3.26	4.97	5	
50	Ⅰ	2.03	3.01	4.14	3.37	3.86	5	97.14%
	Ⅱ	2.31	1.61	4.15	2.08	3.29	5	
	Ⅲ	1.21	3.15	3.39	2.67	3.06	5	
	Ⅳ	2.68	0.67	2.22	2.53	1.38	5	
	Ⅴ	3.91	1.78	4.35	5.32	1.95	4	
	Ⅵ	2.18	2.36	4.57	3.68	2.93	5	
	Ⅶ	0.76	0.78	3.23	2.55	3.64	5	

The above bagging test verifies that the bagging machine maintains normal operation under this control system, while combined with the results in the table above, it can be seen that the weighing error rate meets the quantitative bagging design requirements, the average weighing pass rate of 96.19%, but there are certain deviations, analysis of the reasons for deviations, one is the impact of electromagnetic interference in the weighing process weighing accuracy, the second is the difference in the size of the bagged potatoes, when the set bagging The second is the difference in the size of the bagged potatoes, when the set bagging mass is small, it is easy to cause a large error rate due to a large denominator in the formula for calculating the weighing error rate, and the third is the impact of the potatoes in the bagging process due to the different positions of each bagging station on the calculation of the quality of weighing, but the control system of the potato diversion quantitative bagging machine can meet the design requirements of quantitative qualified bagging.

V. Conclusion

(1) A potato bagging machine control system is designed, while the relevant hardware and software design, and through the corresponding logical sequence to achieve the coordination of multiple bagging mouth efficient bagging, the use of PLC processing information to control multiple electromagnetic reversing valve to achieve the automation of fixed-weight bagging, to achieve the design goal of stable control and effective reduction of bagging error rate.

(2) Bagging performance tests show that: the multi-station potato weighing bagging machine control system weighing pass rate ≤ 2%, its error rate is much lower than the manual bagging, can replace the manual better to complete the fixed-weight bagging work.

Reference

[1]. ZHOU K, JENSEN A L, BOCHTIS D, et al. Simulation model for the sequential in-field machinery operations in a potato production system[J]. Computers & Electronics in Agriculture, 2015, 116: 173-186.

[2]. WANG Xiangyou,SUN Jingbin,XU Yingchao, et al.Design and experiment of paddle roller push type potato cleaning and sorting machine[J]. Transactions of the Chinese Societyfor Agricultural Machinery,2017,48(10):316-322+279.

[3]. Lv JQ, Shang QQ, Yang Y, et al. Design optimization and experiment of potato seedling killing machine[J]. Transactions of the Chinese Societyfor Agricultural Machinery,2016,47(05):106-114+98.

[4]. WEI Zhongcai,LI Hongwen,SUN Chuanzhu,et al. Improvement of potato harvester with vibration and wave secondary separation[J]. Journal of Agricultural Engineering,2018,34(12):42-52.

[5]. Li Na, Zhou Jin, Cui Zhongkai, et al. The current situation of full mechanization of potato production in Shandong Province and suggestions for countermeasures[J]. China Journal of Agricultural Chemistry,2019,40(01):198-204.

[6]. Xie Kaiyun, Qu Dongyu, Jin Liping, et al. Comparison of potato production in China with advanced countries in the world[J]. World Agriculture,2008(05):35-38+41.

[7]. Liu Zicheng,Wang Zhikun,Li Xinxin,deng.Research and design of multifunctional grain collecting and bagging machine[J]. [...] Heilongjiang Science and Technology Information,2015(19):26.

[8]. Hu Zhouxun, Wang Xiangyou, Li Xueqiang, et al. A simple and practical potato bagging machine [P]. Chinese Patent: 201810262304.3, 2018-07-06.

[9]. Lu Xianghui. Design and research of 4U-1400 type potato combine harvester[D]. Gansu Agricultural University,2015.

[10]. Lian Wenxiang. Research and design of grading and bagging device and frame of 4U-1400FD potato combine harvester[D]. Gansu

Agricultural University, 2010.
[11]. Siemens Ltd. In-depth and easy to understand Siemens S7-200SMARTPLC [M].Beijing: Beijing University of Aeronautics and Astronautics Press, 2015.
[12]. Wang YH. Modern electrical control and PLC application technology [M]. Beijing: Beijing Aerospace University Press, 2013.

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