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Design and implementation of automatic apple crating robot technology

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***Abstract*—In this paper, in order to automate the apple packing process using robotics, we designed a set of automatic apples packing robot equipment, which can realize the function of automatic picking and automatic packing of apples placed on round trays in a single row as required. This paper will firstly design a set of assembly line which can transport the graded apples to the operation area for boxing operation, and then transport the completed boxed cartons to the encapsulation area. Then, according to the design parameters of the assembly line, the body, drive system and control system of the boxing robot were designed and the overall 3D modeling of the equipment was completed. Finally, through simulation experiments, it was found that the robot could grasp up to 5 apples at one time, and the robot's grasping success rate was 99% and above. The robot can automatically identify empty trays and carry out selective grasping. It has alarm and catching mechanism for abnormal conditions, so this design can well replace manual work for all-weather and high-efficiency apple crating operation, which is of certain significance for mechanized automation of apple industry.**

Keywords-Automatic apple crating; Automatic pick-up; Robotics

I. INTRODUCTION

With the continuous improvement of China's apple production, packaging industrialization and scale in recent years, and the continuous development of China's express industry and bulk logistics. The efficiency of manual crating has gradually become a major constraint to the development of the apple industry, so how to improve the efficiency of apple crating has become an urgent problem to be solved.

In this paper, a robot is designed to replace the manual packing on the packing line from the actual production requirements. The robot consists of electric cylinder slide, end multi-functional fixture, etc. The length of the end jig slots can be determined by clamping apples of different diameters several times, which reduces the damage to the skin of apples and is more intelligent. The robot has the advantages of flexible movement, small footprint and easy operation, which can realize automatic grasping, moving and placing of apples placed in a single row on a round tray. Therefore, it is more suitable for large quantity of apple crating work.

II. PROCESS FLOW DESIGN

In order to realize the fully automatic packing of apples, this paper firstly designs a set of process flow for this link, and the specific steps are as follows.

First, the graded apples are placed in trays and transported to the robot's work area via a two-lane tray roller conveyor.

Next, a limit device in the work area holds the pallet in the work area waiting for the robot to complete the crating operation.

Then, the detection system detects whether there are missed apples after the robot finishes boxing, and if so, activates the alarm and catch-up mechanism.

Finally, after determining the completion of the gripping operation the limit device releases the empty pallet and the robot grabs the partition and puts it into the packing box.

III. APPLE AUTOMATIC PACKING LINE DESIGN

In this paper, in order to realize the fully automatic packing of apples, an automatic apple packing line is firstly redesigned on the basis of the traditional manual packing line according to the working characteristics of robots. Its overall layout is shown in Figure 1.

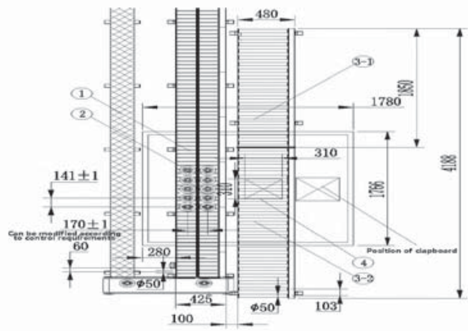

Fig. 1 Layout of double-lane pallet roller conveyor

(1) Double passage pallet roller conveyor. (2) Apple trays. (3) Two sections of fruit box conveyor. (4) Fruit boxes.

In Figure 1, a double-lane pallet roller conveyor carries apple pallets that first carry the pallets containing graded apples to the robotic work area, and then carries the empty pallets to a

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conveyor belt that recovers the empty pallets. The key design parameters are shown in TableI.

TABLE I, DOUBLE CHANNEL PALLET ROLLER CONVEYOR (UNIT: MM)

Height	Total width	Effective internal width	Shipping Speed	Roller diameter	Roller axis distance
850	425	360	0.85m/s	50	60

In Figure 1, the fruit tray is used to hold the apples that have been graded to move on the double-lane tray conveyor. The design size of the fruit tray and other key parameters can be determined according to the actual size of the apples as shown in Table II.

TABLE II , FRUIT TRAY (UNIT: MM)

Diameter	Height	Double-channel fruit tray spacing	Fruit tray conveying table height
141±1	60±1	170±1	850

In Figure 1, a fruit box conveyor is configured, which is mainly responsible for transporting the loaded apple boxes to the encapsulation area. Considering the quality change before and after packing, the conveyor of fruit boxes is designed as two-stage, and the rest of the key design parameters are shown in Table III.

TABLE III, TWO SECTIONS OF FRUIT BOX CONVEYOR

Height	Total width	Effective internal width	Shipping Speed	Roller diameter	Roller axis distance
550	480	415	0.35 m/s	50	103

In this paper, according to the fruit box size as shown in Figure 2, the figure shows a two-layer 3×3 boxing scheme, according to the size of the apple diameter, this paper also considers two other boxing schemes, distinguishing two layers of 4×4 and two layers of 5×5. Collate its internal packing scheme as shown in Table IV.

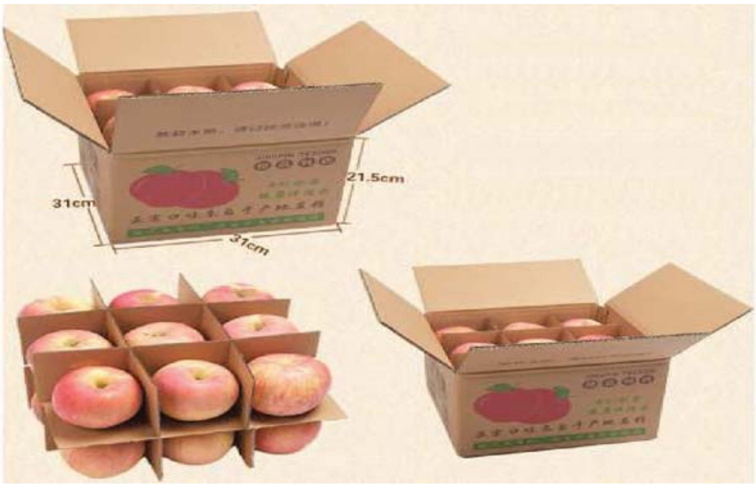

Figure 2 Physical drawing of fruit box size

TABLE IV, FRUIT BOX AND BOXING DESIGN

Case size	Apple Arrangement 1	Apple Arrangement 2	Apple Arrangement 3
310mm×310mm×215mm Fruit weight 5 kg/ctn	3×3(85-95mm Fruit Diameter) 2 layers per box	4×4（65-75mm Fruit Diameter） 2 layers per box	5×5 (50-60mm Fruit Diameter) 2 layers per box

IV. CARTONING ROBOT BODY DESIGN

Apple automatic packing robot can realize the function of apple sorting and grasping automatic packing. The robot is mainly composed of robot arm and end multifunctional fixture. The length of the end fixture slots can be determined by clamping apples of different diameters several times. The robot consists of actuator, drive system, control system and other parts, which can realize high-efficiency automatic apple crating production.

A. Adaptive end fixture design

In order to make the robot more versatile and flexible, the end fixture structure of the machine is designed as a clamping device with U-slot type replaceable structure. In addition, the end-effector uses silicone suction cups in order to reduce the damage of the end-effector to the skin of the apple. The movement of the apples is achieved by the principle of negative pressure. The actuator section at the end of the manipulator is shown in Figure 3 below.

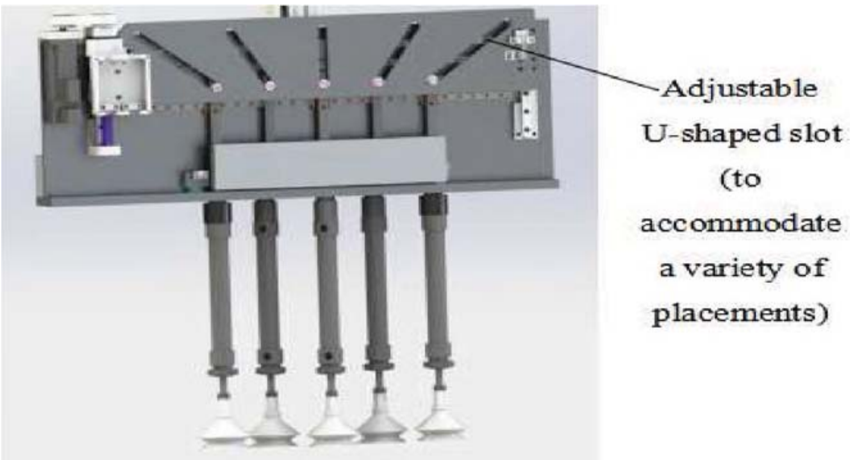

Figure 3. 3D modeling of the end-effector

B. Robotic arm body design

According to the parameters determined in the previous process design, the position of the robotic arm in relation to the other components is shown schematically in Figure 4.

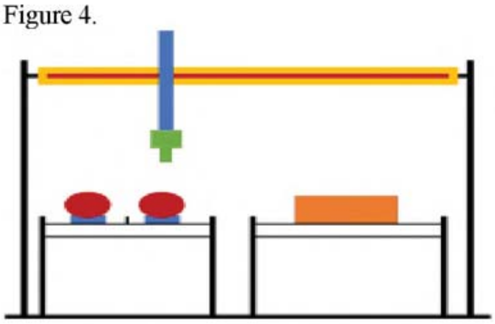

Figure 4 Schematic diagram of robot arm motion relationship

In Figure 4, the robot arm body is a two-degree-of-freedom right-angle coordinate type robot arm, consisting of two linear mechanisms, and firstly, the plan and axonometric drawings of the robot arm are drawn according to the process design parameters as shown in Figure 5.

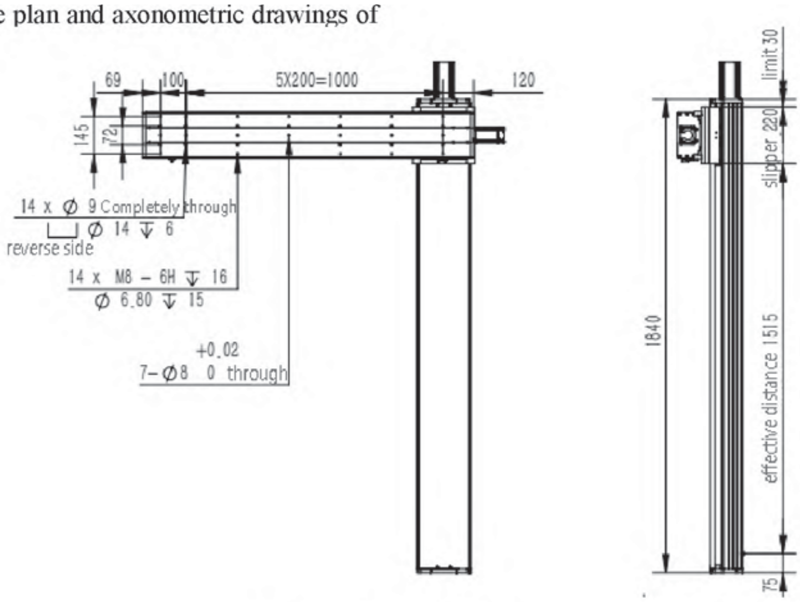

Fig. 5 Dimensional design of robot arm body

After modeling the robot arm body in 3D according to the design dimensions in Figure 5 and then assembling the end-effector, the robot body model is shown in Figure 6.

Figure 6 Robotic body model

TABLE V. EQUIPMENT DESIGN PARAMETERS

Power supply/power	Packing beat	Equipment appearance size	Robot parameters
380V 50/60HZ	3.5s/sec	1780×1766×1880mm	X-axis effective travel1450 Y-axis effective travel 900 Rated load 50KG

V. WORKING PRINCIPLE

The apples to be boxed are delivered by the conveyor belt to the working radius of the robot, which should be directly above the conveyor belt at this time to ensure the shortest possible time for the whole robot working process. The robot performs the following actions to perform the task according to the specified program.

- Descending: controlled by the lifting cylinder of the slide, the end suction cups are adjusted to open a certain distance through the U-slot during the descending process to prevent damage to the apple.
- Grabbing apples: done by the end clamping cylinder.
- Rise and rotate to adjust to the pre-release angle: done by the slide lift cylinder and rotating cylinder together and move to the top of the corresponding dispensing conveyor.
- Descent: achieved by the slide lifting cylinder.
- Put down the apple: the process is completed by the end clamping cylinder.
- Rise and rotate: done by the slide lifting cylinder and rotating cylinder together, and the robot is restored to the initial position.

The above is only the actions to be performed by a workflow manipulator. Due to the different sizes of apples, they need to be sorted into boxes so multi-station design is used. The robot can reduce the damage to the skin of the apple, and the degree of intelligence is high. The robot has the advantages of flexible movement, small footprint and easy operation. The 3D modeling of the overall crating line is shown in Figure 7.

Figure 7. Overall 3D modeling of the equipment

VI. EXPERIMENTAL RESULTS AND ANALYSIS

Simulation of the entire assembly line operation process in the 3D software yields the following results. Apples that should have a maximum fruit diameter range of 50 to 120 mm. The working range of the robot is 1500mm stroke of X-axis and 1000mm stroke of Y-axis. The maximum number of apples that can be grasped at one time is 5, i.e. the maximum number of five fruit trays can be set. The beat is less than 3.5 seconds; the success rate of grabbing ≥ 99%, i.e., continuous grabbing 100 apples and automatic boxing, the number of successful boxes is greater than or equal to 99.

VII. CONCLUSION

Through experiments and analysis, the success rate when boxing has reached the actual production needs, but because there may be empty pallets coming continuously, the robot is designed to automatically identify and perform selective grasping. Due to the presence of empty pallets and abnormal ungraspable apples, the robot also has an alarm and catch-up mechanism that can make up for the actual situation and achieve correct boxing. Therefore, this design can well replace the manual work for all-weather high-efficiency apple crating operation, which is of certain significance for the mechanized automation of apple industry.

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