Automatic Turning Manipulator for Cake Production Line

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Abstract—In the production process of baking food processing enterprises, cakes, biscuits and other products made by steaming are generally installed in the baking tray and baked in the oven. The temperature of the baking tray is above 100 degrees Celsius when leaving the oven. The high temperature environment is not conducive to the protection of workers. It needs to be left to cool and then be transported, so the production efficiency is low. In order to solve this problem, a method of replacing the manual handling of the baking tray and removing the baked cake product with a turning robot is proposed. At the same time, two methods for improving the design of the cake production line are given, and the structure and use of the two products of the single-column turning manipulator and the articulated turning manipulator are introduced. The single-column turning manipulator consists of a base, a single-column rotating mechanism, a lifting mechanism, a swing arm, a pneumatic gripping mechanism, etc. A frame-type pneumatic gripping mechanism is adopted, and driven by the turning motor, and can realize the turning of the baking tray. The articulated turning manipulator consists of a base, a waist, a big arm, a small arm, a wrist, and a hand actuator. The hand adopts a rotatable square shaft end structure with an electromagnetic device, transforming the cake baking tray to increase the square groove meshed with it, so as to realize the flipping action of the cake baking tray.

1. Introduction
With the development of modern science and technology, various industries are moving towards automation, and food production enterprises are no exception. Most modern cake manufacturers use automatic cake forming machines, the principle of which is injection molding, which is mainly composed of storage cylinders, beating cylinders, firing systems, conveying systems and control systems. The equipment can automatically control the injection of cake paste into the baking tray, and then the baking tray is sent to the oven for baking[1]. The baking process is a high-temperature environment, which has high requirements for worker protection. After the cake is steamed and baked, it needs to be left to cool for a while after being put out of the oven, and then the workers wear protective gloves to remove it, and then take the cake out of the baking tray. In this traditional production method, there is a lot of waiting time after roasting. Not only does the low utilization rate of the baking pan lead to low production efficiency, but it may also cause burns to workers. For this
reason, the author proposes to design a cake automatic turning manipulator to transport the baking tray and take out the baked cake at the same time. After investigation, it is found that the specifications of commonly used baking trays have been standardized, most of which are 600×400×50 (mm). The temperature of the baking tray is over 100°C when the tray is turned. Therefore, the idea of designing an automatic turning manipulator is feasible, and the original production process can be transformed. An assembly line can be added to match the automatic turning manipulator to improve the automation level of the cake production process.

2. Renovation plan of cake production line

As shown in Figure 1, there are two automatic production lines next to the oven, one is to receive the cake, the other is to recycle the baking tray; there are two kinds of movement of the manipulator between the production lines: (a) turn 90°, (b) turn 180°.

In order to meet the requirements of the production line, it is necessary to design an automatic turning manipulator with no less than four degrees of freedom. The design of the automatic cake turning manipulator needs to solve the two key issues of how to grab and how to turn the cake. The following describes the structure and use of the two products of the designed single-column turning manipulator and articulated turning manipulator.

![Diagram of production line transformation plan](image.png)

1. Line 1; 2. Guide post; 3. Cake baking tray; 4. Pneumatic mechanism; 5. Line 2; 6. Base + single-column rotating mechanism; 7. Lifting mechanism; 8. Swing arm

(A) Turn 90°

![Diagram of turning 90°](image.png)

1. Oven; 2. Hot baking tray; 3. Production line; 4. Recycle bin; 5. Empty baking tray

(B) Turn 180°

![Diagram of turning 180°](image.png)

Figure 1 Production line transformation plan
3. Design of single-column turning manipulator

The driving methods of the manipulator are mainly pneumatic, hydraulic and electric. They have their own advantages and disadvantages and adapt to different working environments[2-3]. The characteristics of the three driving modes are shown in Table 1.

| Drive method       | Motor drive | Hydraulic drive | Pneumatic drive |
|--------------------|-------------|-----------------|----------------|
| **Driving force**  | Larger      | Big             | Small          |
| **Control performance** | High control precision, sensitive response, and complicated control system | High control accuracy, large output power, and sensitive response | Low precision, low speed and difficult to control |
| **responding speed** | Fast        | Faster          | Faster         |
| **safety**         | The motor requires explosion-proof and leakage-proof | Good explosion-proof performance | Good explosion-proof performance |
| **the effect on the environment** | None        | The hydraulic system is prone to oil leakage and pollutes the environment | Noise during exhaust |
| **Cost**           | Higher      | Higher          | Lower          |
| **Use and maintenance** | Convenience | Convenient, oil has environmental requirements | Convenience |
| **Scope of application** | Manipulator with small and medium load, high position control accuracy and trajectory | Heavy-duty, low-speed drive | Manipulator driven by small and medium-sized loads, with limited accuracy and limited point program |
The single-column turning manipulator is driven by electric drive and pneumatic method, and its structure is shown in Figure 2-4. It consists of a base, a single-column rotating mechanism, a lifting mechanism, a swing arm, and a pneumatic gripping mechanism. A frame-type pneumatic gripping mechanism is adopted, and driven by the turning motor, and can realize the turning of the baking tray.

The base supports the upper structure such as the column, and the lower part is connected and fixed to the ground, and the column is driven to rotate by the internally installed motor, reducer, coupling and other components. The lifting mechanism is composed of lifting motor, screw, nut mechanism and other components. The lifting motor is vertically installed on the upper part of the column and fixed to the column. It is connected to the screw through a coupling. The screw is supported by the bearing (shaft sleeve, etc.) up and down inside the column. At both ends, the nut mechanism is connected to the lead screw while cooperating with the side opening of the upright, and can slide up and down along the upright. The outer side of the swing arm and the nut mechanism move up and down with it. The other side has a built-in turning motor, and the outer side is processed with a matching surface. The output shaft of the motor passes through the swing arm and is connected to the pneumatic gripping mechanism. Cooperate with the outer circle of the swing arm to prevent the grab mechanism from tipping over. Pneumatic grasping mechanism adopts integral frame structure, two cylinders and a guide column driving clip are arranged on both sides, and the side of the clip and the cake baking tray is vulcanized with high temperature resistant rubber.

The working process is:

- **Clamping tray:** The pneumatic gripping mechanism rotates to the top of the cake baking tray to be transferred along with the rotating arm, then falls to the outside of the cake baking tray along with the lifting mechanism. The cylinder intakes air, and the piston is pushed to drive the clamping strip to clamp the cake baking plate.

- **Lifting:** The lifting motor starts the forward rotation, and the rotating arm and the pneumatic gripping mechanism are lifted 60mm through the drive of the screw nut pair.

- **Conversion station:** The column rotation motor starts to rotate forward, and the column rotates counterclockwise through 90° to line 2. While the column rotates, the turning motor starts to rotate forward, driving the pneumatic gripping mechanism to turn 180°.

- **Lower:** The cylinder stops the air intake and exhaust, the clip releases the cake baking tray, and falls to the No. 2 line.

- **Return position:** The column rotation motor starts to reverse, and the column rotates 90° clockwise to return to the top of the No. 1 line; the lifting motor starts to reverse, and the rotary arm and pneumatic gripping mechanism are lowered by 60mm through the drive of screw nut pair.

Repeat the gripping cycle.

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| control accuracy, and high speed | control |

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1. Centralizer sleeve; 2. Rotary connecting shaft; 3. Clamping strip; 4. Grabbing disc cylinder; 5. Guide post

Figure 2 pneumatic gripping mechanism
1. Centralizer sleeve; 2. Mating with cylindrical surface; 3. Turning motor; 4. Rotating arm

Figure 3 Turning mechanism

1. Base; 2. Column rotating motor; 3. Column; 4. Lead screw; 5. Shield; 6. Lifting motor; 7. Nut mechanism; 8. Rotating arm; 9. Turning motor; 10. Centralizer sleeve; 11. Clamp cylinder; 12. Guide column

Figure 4 Single-column manipulator

4. Design of articulated manipulator

The structure of the articulated turning manipulator is shown in Figure 5-6. It consists of a base, a waist, a big arm, a small arm, a wrist, and a hand-executing device. The structure is similar to the general six-degree-of-freedom industrial robot[4-5]. The base supports the weight of the manipulator, and the inside is hollow. The waist sits on the base, and the mechanical arm is connected to withstand large torque, and adopts a fork-shaped structure design. The mechanical arm supports the wrist and hand, and at the same time transfers the movement of each axis in series to the execution end, requiring that the workpiece in the hand can be sent to the designated working position. The wrist connects the hand execution device and the arm, supports the weight of the hand, and drives the hand movement. The
hand is designed as a rotatable square shaft end structure with an electromagnetic device. The cake baking tray is modified to increase the square groove that meshes with the hand square shaft end to achieve the flipping action of the cake baking tray. Using the positioning point on the square axis as a reference point, the algorithm of spatial motion is used to compile the robot control program to control the comprehensive motion of the waist, arm, arm and wrist of the robot. Align the square shaft with the position of the square groove of the baking tray, then start the electromagnetic lock to grasp the baking tray, and after lifting a certain distance, control the rotating motor to drive the square shaft to rotate to realize the flipping movement of the cake baking tray.

![Diagram of hand structure](image1)

1. Wrist; 2. Square shaft end; 3. Baking tray square groove

Figure 5 Schematic diagram of hand structure

![Diagram of articulated manipulator](image2)

1. Base; 2. Worm gear mechanism; 3. Waist; 4. Big arm; 5. Small arm; 6. Wrist; 7. Hand

Figure 6 The overall structure of the articulated manipulator

All motion mechanisms are driven by motors. The worm gear drive has a relatively large transmission, high transmission efficiency, and a compact structure. It is used for the first shaft that
connects the base to the waist and realizes the function of rotating around the Z axis. The second shaft connected to the waist and the big arm, and the third shaft connected to the big arm and the small arm are driven by cycloidal planetary gears, and the motor is installed at the joint. The wrist is driven by a synchronous toothed belt, which can obtain stable transmission and high transmission efficiency. The motor is connected to the wrist joint by a concentric sleeve. In order to achieve higher control accuracy, each axis is selected to be driven by a servo motor with high control accuracy and fast response speed.

5. Conclusion
(1) The plan for the transformation of the cake production line has been proposed, which can improve the automation level of baking food production enterprises and help to solve the problems of poor labor protection, low production efficiency, and difficulty in recruiting workers.

(2) Single-pillar turning manipulator and articulated turning manipulator have been designed. The single-column turning manipulator consists of a base, a single-column rotating mechanism, a lifting mechanism, a swing arm, a pneumatic gripping mechanism, etc. A frame-type pneumatic gripping mechanism is adopted, and driven by the turning motor, and can realize the turning of the baking tray. The articulated turning manipulator consists of a base, a waist, a big arm, a small arm, a wrist, and a hand actuator. The hand adopts a rotatable square shaft end structure with an electromagnetic device, transforming the cake baking tray to increase the square groove meshed with it, so as to realize the flipping action of the cake baking tray.

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