Research on volume compression control system of solid and liquid food in bowl based on PLC

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Abstract. In order to solve the problem of liquid and solid food products in bowls produced by enterprises, the liquid and solid food products spilled during manual operation of food compression process. Product weight reduction affects production efficiency and labor intensity of workers. The specific control parameters are obtained through the orthogonal experimental design and observation method. Adopt digital control technology and design method of mechanical structure. The numerical control system can precisely control the movement and rotation of the pressure plate, and realize the numerical control functions of position, speed and force Angle in the compression process. The touch screen and PLC are the control core. Photoelectric sensor to obtain position parameters, servo motor drive screw linear module slider movement, stepper motor drive disk rotation Angle, touch screen to achieve man-machine interface. It provides research basis for further optimization and numerical control system of different solid-liquid food materials compression.

1. Introduction

With the rapid development of China's market economy and the improvement of people's living standards, food packaging with delicate solid-liquid mixture in bowls is becoming more and more popular. The volume compression of solid and liquid food in bowl is an important step in bowl packing. Many enterprises in China manually quantitative processing bowl of solid and liquid food materials volume compression food station operation, manual operation is not only unsanitary, and the production efficiency is relatively low. The force, speed and position of solid-liquid food materials in the volume compression of the bowl are not evenly controlled by manual operation. During the volume compression, the soup and food materials are easy to overflow in the gap between the bowl and the bowl cover. In the production process, the weight of products is reduced, and the unqualified rate is increased. In addition, many food materials have higher hardness after freezing, and the volume compacting and compression of solid and liquid food materials is of great labor intensity [1].

Most enterprises use mechanical tools for processing, and the bulk compression process of solid and liquid food materials in bowls is relatively sanitary. However, the processing efficiency is not high enough, and the compression position, speed and force direction are not evenly controlled, which may easily lead to the overflow of soup and food materials in the matching gap of bowl and bowl cover during the compression process. The United States, Germany, Japan and other developed countries developed earlier in the food industry and carried out continuous research. These countries achieved a higher degree of automation. Developed countries common solid food bowl compression food device can only solve solid food compression. The machine meets the packaging requirements of solid food packaged in bowls, and has strong stability, which is widely liked by large domestic food enterprises.
However, at present, there are no manufacturers of volumetric compression equipment for solid and liquid food materials in bowls at home and abroad. Therefore, the volumetric compression control system of solid-liquid food for bowl packing is an innovation in food machinery, which fills the blank of the volumetric compression control system of solid-liquid food for bowl packing.[2]

In this paper, digital control technology and mechanical implementation of the structure of the method. By adjusting the shape of the pressure plate and according to the execution program in the computer memory. Study on the numerical control function of position, speed and force direction in the moving up and down of digital control platen. Thus precise control of bowl food compression process pressure plate position, speed and force direction parameters, adjust the pressure plate finger Angle parameters. Prevent the spillage of solid and liquid food materials during the compression process, replace manual compression, and improve the quality and efficiency of bowl food production.[3]

2. Overall design of test system

2.1. process analysis

The process flow is shown in figure 1. Due to the uneven control of pressure velocity, position and force direction in the process of artificial compression of solid-liquid food mixture. Manual compression process up and down more than 20 times to complete the compression process, the inevitable extrusion of food soup. After the completion, manually wipe the bowl and add a small amount of food materials to ensure the qualified rate of the product.

As shown in figure 2. In order to prevent the liquid from being extruded during the artificial compression of solid-liquid mixture. Early through a lot of observation manual work. It is found that the surface of solid and liquid food is convex, which increases the space in the bowl and makes the food soup not easy to be squeezed out. Therefore, we get the result that in the process of pressing the plate, the solid and liquid food materials in the bowl must be subjected to local pressure and the pressure forms a certain Angle. Only after the compression is completed, can the food liquid not overflow easily. However, after many tests, the finger Angle of the pressure plate was changed to make the solid and liquid food materials in the bowl under partial pressure and form a high pressure zone. This method can only reduce the rate of spillage by 40 percent.[10]

In the further experiment, the pressure plate with Angle is used to collect the parameters of rising position, falling position, rising speed and falling speed in the compression process. Precise digital control of rising position, falling position, rising speed and falling speed is adopted for the test. Since there are many factors in the study and a large number of experiments are required, orthogonal design experiment method is used to select some representative points from the comprehensive experiment for the experiment. Thus, the effective parameter values can be obtained efficiently, rapidly and economically.[4]

Seven factors three-level orthogonal test was used. The test condition was 650g per bowl, and the number of test bowls was 5*18=90 bowls. The test factors were an umbrella camber with its levels of 0mm, 5mm and 10mm; B drop pulse its level of 35,000, 36,000, 37,000; C decrease frequency at levels 5000, 20000, 60000; D rise frequency of its level 5000, 20000, 60000; E. Horizontal unilateral four leaves, symmetrical bilateral eight leaves and symmetrical sixteen leaves on four sides in the high pressure area: the bending level of F in the high pressure area is 5mm, 10mm and 15mm; G rise pulse its
level 1000, 2000, 3000. The orthogonal table of seven factors and three levels was used to determine the best process conditions, A2 B2, C2, D2, E2, F1, G1. So as to ensure that the press plate reciprocates up and down and rotates through slapping solid and liquid food materials for several times, finally the slapping surface forms a convex surface and solid and liquid food materials are not extruded at all. Products no longer reduce the weight and pollution of the bowl, not only improve the efficiency of bowl food production and conducive to packaging.

2.2. system hardware design
The control technology of programmable logic Controller is a new type of industrial control technology that combines automation technology with computer technology. PLC program designers can use instruction programming, ladder diagram, functional block programming language to complete the required action. Therefore, 20% to 30% of I/O ports are reserved, depending on the number of input/output signals, storage capacity, and control requirements [5].

As shown in figure 3, this design selects the ex2n-43h series 16MT touch screen and PLC as the control core of this system. PLC controls the servo motor to make the linear module move up and down. The servo system driver USES panasonic A6 series MBDLN25SE, and the servo motor USES the same panasonic MSMF042L1V2M motor. The system adopts closed-loop design, which can feed back the measured value in time, and finally realize accurate control. For the linear module, shenzhen boao company's width ontology 126mm and effective travel 300mm screw transmission linear module are selected [6]. RISYM 42BYGH34 plug-in motor, torque 0. 28n /M, TB6600 maximum output current 4.0A, and 16 maximum subdivision are selected for the drive control board. Panasonic PML45 photoelectric sensor is used for position control and positioning [8-9]. The mechanical actuator is designed as finger-like pressure plate, which is made of 316 food grade stainless steel plate [7].

![Hardware connection diagram](image)

Figure 3. Hardware connection diagram

After the completion of the hardware connection, the motion travel is to use the linear screw module to build the slide track, and PLC drives the servo motor to move up and down as the slider of the linear module. The stepping motor is connected with the motor bracket on the slider of the linear module, and the stepping motor is connected with the tamping rod with a coupling.

2.3. system software design
As shown in figure 4, the specific process of the control system for the volume compression of solid, liquid and food materials in bowls is as follows :(1) start the program to detect whether the PLC system fails. If it fails, the PLC system stops working and gives an alarm. If nothing goes wrong, the program is started and initialized. (2) check whether the equipment is in fault, if it is in fault, the equipment will stop working and give an alarm; If there is no fault, move on to the next step. (3) judge the operation mode, including automatic operation and manual operation, among which the automatic operation process is complex. During the compression process, the equipment judges whether there is zero return or not. If not, the equipment first returns to zero; If at zero, continue to work until the end of compaction.
On the other hand, manual operation requires the operator to manually set the procedure and judge the whole process until the end of compaction.

As shown in figure 5, this control system USES the ex2n-43h series 16MT touch screen and PLC integrated machine. It is compact in structure, convenient and flexible to set control parameters and real-time monitoring system running state and effective management of the system. The programmable logic controller USES GX Works software for program programming design. The touch screen USES a variety of control device libraries, graphics controls and functional controls provided by GoolMay HMI, which can configure various dynamic functions and control functions, and realize fault visualization. And can read the PLC data, display the field status data.

![Figure 4. Control system flow chart](image1)

![Figure 5. Touch screen display interface](image2)

3. **Numerical control system application experiment**

In this experiment, the condition is that the bowl contains 650g of solid and liquid ingredients, including 530g of solid ingredients and 120g of soup. The number of test bowls is 90 and the weight of each bowl is exactly the same. Test 18 groups and 5 bowls in each group to ensure the stability of test data. By changing the PLC control servo motor speed, so as to control the pressure plate down pulse, pressure plate down frequency, pressure plate down times, pressure plate up pulse, pressure plate up frequency. By changing the PLC control of stepping motor rotation speed and direction, and control the pressure plate rotation frequency and the rotation direction, cooperate with mechanical pressure plate shaped camber in compression test, is a good way to avoid the artificial compression in the process of solid-liquid mixed ingredients down too fast is easy to spatter ingredients juice, up and down reciprocating compression pressure from the more than 20 times to complete work, realize the digital control technology in the process of compression tamping have been pushed out to the various factors on the ingredient soup bowl edge minimum extent.

The control system of volume compression of solid and liquid food materials in bowl has been tested for many times with the method of controlling parameter value.

4. **Conclusion**

The continuous growth of the demand for bowl food promotes the continuous development of the food compression machinery industry of solid-liquid coexistence of bowl food. Adopt digital control technique and method of mechanical execution configuration. By observing the principle of artificial compression and orthogonal test, the optimal process parameters of velocity, position and force direction A2 B2, C2, D2, E2, F1, G1 were obtained. Realize the digital precise control of the position, speed and force Angle of the pressure plate in the compression process. Solve the overflow of soup and food materials in the space between bowl and bowl cover during the volume compression of solid and liquid food materials. Servo motor is used to control the up and down motion stroke scheme to improve
the accuracy of compression frequency and compression position. The scheme of stepper motor controlling the rotation of the press plate is adopted to improve the uniformity of compression and the flatness of compression surface. This paper discusses the hardware configuration and software application in detail. It provides a research basis for further optimizing the optimal conditions of CNC compression system and different compression equipment.

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