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DESIGN OF CONTROL SYSTEM FOR ALCOHOL ETHER FILLING MACHINE BASED ON MACHINE VISION AND PLC

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ABSTRACT

A fully automatic alcohol filling machine system based on the combination of vision and PLC program of the machine is designed. The mechanism of the fully-automatic filling liquid system is mainly adopted from PLC technology and stepper motor control technology. At the same time, in order to control the filling quality precisely and accurately, the system itself comes with an automatic computed sensor and a fully automatic weighing machine in the system. The system adopts a successive approximation control method with an accurate barrel port addressing function, it can be addressed to the function such as alcohol ether liquid filling successfully.

KEYWORDS

Filling machine, Machine vision, PLC, Successive approximation control method.

1. INTRODUCTION

The packaging of the liquid products is mostly accomplished by the machines itself. Filling industry in China has experienced the process of technology introduction and modification which results in self-development of the technology. It is widely used in the liquid filling machines, especially in the growing demand for chemical alcohol ether canning industry. Automatic filling machines have gradually replaced manual or semi-automatic filling, and it will become the essential equipment for the alcohol ether filling industry. For the requirement of large-capacity and high-precision filling in the petrochemical industry, a fully automated metering and filling system is designed. In terms of automation control, the system has combined the machine vision technology, stepper motor control technology, and PLC position control. Furthermore, the operator and filling errors have been reduced which leads to higher and greater productivity. The optimal control of the entire production line has been achieved and at the same time the market has a great potential for development.

2. THE COMPOSITION AND THE MECHANISMS OF THE SYSTEM

The system is mainly composed of machine vision automatic addressing system, PLC program control system and stepper motor control system, an automatic weighing and weighing control system, etc. The program control system adopts Siemens S7-300 PLC series, which is complement to the other programs. Besides that, the PLC is connected with various inspection and sensor devices which able the system to communicate with the monitoring computer (upper computer) through industrial Ethernet to obtain various production monitoring parameters, through the visual identification system, stepper motor control system and position detection. In order to control the movement of filling equipment and filling speed, it is through the weighing system to allow the system to control the liquid filling. For the production process, the used of programmable controllers at the barrel mouth allow the system to calculate along with an automatic metering system program for switching. With the highly precise and accurate system, it enhances the overall production line. The block diagram of the system is shown in Figure 1 [1-5].

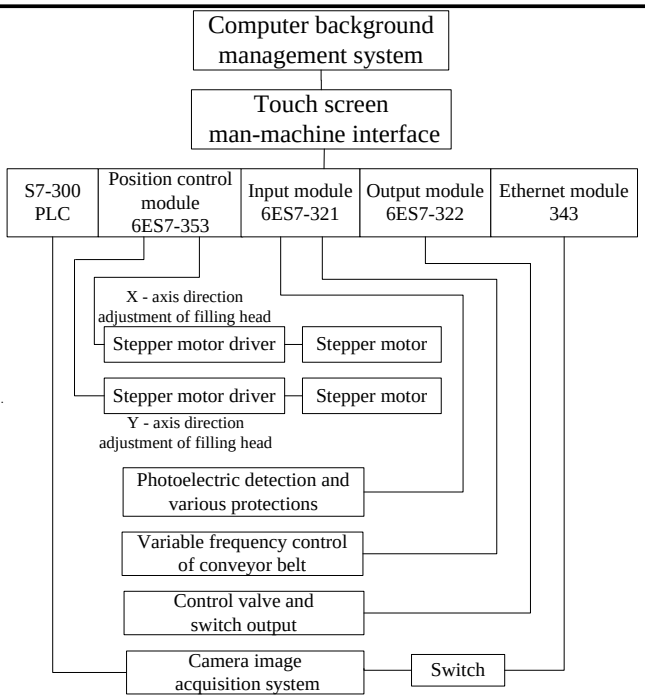

Figure 1: System block diagram

3. SYSTEM HARDWARE DESIGN

3.1 Machine Vision System

The machine vision addressing system consists of a visual image acquisition and analysis system, a two-degree-of-freedom platform

control system, a canned weighing and measuring mechanism, and a track transport control mechanism. In Figure 2, the machine vision addressing system enables the automatic positioning of the barrel holes of the vessel by the spray gun, which not only reduces the labor and filling errors but also greatly increases the productivity [6]. The system is made of stainless steel which is a strong corrosion resistance metal and it is able to withstand moisture. It can be used in any environments especially industries that involved chemical such as petroleum, chemical, dye, grease, paint and other industries.

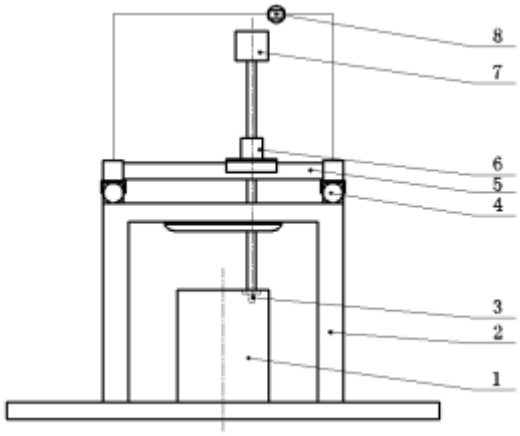

Figure 2: Machine Vision System Structure: 1. Filling barrel, 2. Bracket, 3. Spray gun, 4. X-axis moving platform, 5. Y-axis moving platform, 6. Stepper motor, 7. Lifting mechanism 8. Camera

3.1.1 Machine Vision Addressing Working Principle

After the empty filling barrel 1 is transferred to the canned position, the image above the container is captured by the camera 8 of the image acquisition system, and the two-dimensional coordinate information of the eccentric barrel hole is obtained through image filtering, calibration, and quick mode matching processing, and this data is used to calculate and plan the PLC program [7]. The best running track of the stepper motor 6, adjustment and control of the stepper motor and lifting mechanism enable the canned spray gun 3 to automatically move to the position of the barrel mouth. This system is not only stable but also has high accuracy and efficiency.

When the photoelectric switch detects that the filling bucket enters the filling position of the preset area, an image is collected. By using the image processing and pattern recognition method, the coordinate value is relative to the set coordinate system in the image is obtained, and the value is recorded [8]. The MODBUS RTU serial communication method is transmitted to the PLC. The PLC control system converts the control pulses that can be recognized by the stepper motor according to a certain interpolation algorithm according to the pixel coordinate data, and controls the movement of the gun to the position of the barrel port.

The spray gun is inserted into the barrel hole of the barrel to be filled by the lifting mechanism. Among them, the lifting position of the spray gun is controlled by a limit switch. When the spray gun reaches into the bucket, the system automatically peels the container to carry out large-flow filling. When it approaches the canned weight, the program control converts to a small-flow can fill. After the filling is completed, the spray gun rises, which not only ensures rapid canning, but also reduces the filling error [2].

3.2 Linear interpolation algorithm

The visual algorithm can find the coordinates of the center point of the bucket mouth in the image, but this coordinate is often not directly referenced and needs to be converted into the moving distance of the two-degree-of-freedom mobile platform. Therefore, the linear interpolation algorithm is needed to calibrate the image along with an accurate trajectory which positioning at the center point.

Linear interpolation can only be used for interpolation where the actual contour is in a straight line. The linear interpolation algorithm is also called the "densification of data points". Furthermore, each step of the stepping motor must be compared with the given data. By analyzing at the specific zone and optimization will take place whether it fall above the threshold level or below the threshold and decide the next step [9]. At the same time, the camera transmits the coordinate value to the PLC, and the PLC converts the X and Y axes. The number of moving pulses is sent to the stepper motor driver. The stepper motor runs according to the given coordinates, so that the two-degree-of-freedom platform moves the spray gun to the barrel port. Just above, automatic positioning of the barrel mouth is realized. The interpolation of the interpolation algorithm coordinates is shown in Figure 3.

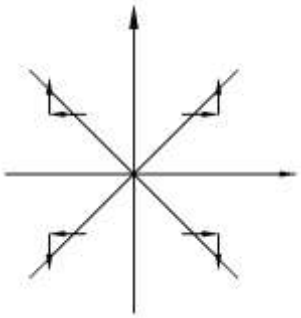

Figure 3: Interpolation Algorithm Coordinate Feeding

3.2.1 Successive Approximation

At present, the interpolation algorithm is divided into two categories, one is the pulse incremental interpolation algorithm, and the other is the data sampling interpolation algorithm. The successive approximation method is the most typical algorithm in the pulse incremental interpolation. During the control process, the deviation of the motion trajectory from the given trajectory is calculated and judged point by point, and the axial given profile is approached and reduced according to the deviation control feed. Deviation makes the running profile approaches the given profile. Features are simple structure, low feed speed, easy to achieve space linear interpolation. In order to make the canning more accurately, this design adopts a new successive approximation method that can guarantee the accuracy requirements and can increase the interpolation speed. That is, when the trajectory moves to the M position, the basis for judging the next feed amount is to simultaneously feed a pulse to X, Y, and XY, respectively, to calculate their deviation Fi+1, and to take the minimum feed of the F_{i+1} absolute value. Actually feed in the direction. As is shown in Figure 4 [3].

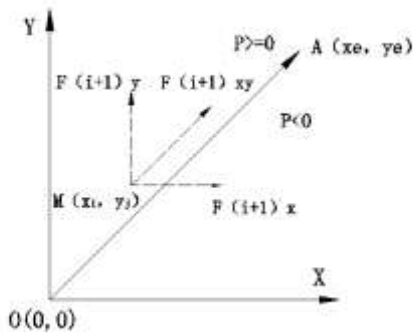

Figure 4: Sequential approximation method schematic

In the new successive approximation method, taking the straight-line OA in the first quadrant as an example, the starting point O is at the origin of coordinates (0,0), the ending point A is(x_e, y_e), and the moving point P（x_i, y_j）is in the straight line Above, then $F_{i,j}>0$, then calculate the values of F_{i+1} that are fed simultaneously to X, Y, and XY,

When feeding one step in X direction, P coordinate value is x_{i+1}, y_j. According to the formula (1):

$$F_{i,j} = x_e y_j - x_i y_e \tag{1}$$

Substituting the coordinate values, as shown formula (2), formula(3):

$$F_{i+1,j} = x_e y_j - x_{i+1} y_e = x_e y_j - (x_{i+1}) y_e = x_e y_j - x_i y_e - y_e \tag{2}$$

$$F(i+1)x = F_{i,j} - y_e \tag{3}$$

Feeding a step in the Y direction: P's coordinate value is x_i, y_{j+1}

$$F_{i,j+1} = x_e y_{i+1} - x_i y_e = x_e (y_{j+1}) - x_i y_e = x_e y_j - x_i y_e + x_e \tag{4}$$

That is formula (5):

$$F(i+1)y = F_{i,j} + x_e \tag{5}$$

When feeding one step in the XY direction, as shown formula(6):

$$F(i+1)xy = F_{i,j} - y_e + x_e \tag{6}$$

After three F_{i+1} calculations are respectively performed, feed is performed according to the feed mode with the smallest absolute value of F_{i+1}. When two absolute values are the same, the feed is performed in the manner of XY simultaneous feed. Different feed directions can be calculated for the four quadrants by analogy.

In the Successive approximation, new processing is performed on the endpoint discrimination of the interpolation. Because the new algorithm sometimes has simultaneous feed of two coordinates, that is, oblique feed. If the coordinates of the X-axis and Y-axis are compared in the past, whether the coordinates reach the end point, or whether the coordinates of the X-axis arrive, or the coordinates of the Y-axis are Arrived, sometimes the wrong end judgment, or in the judgment process can never meet the judgment conditions. In order to prevent this from happening, we first need to figure out the number of steps that are fed to X and Y respectively. When we encounter a step toward X or Y, we subtract one step from the total number of steps. When X and Y are fed simultaneously, the two steps are subtracted from the total number of steps so that when the number of steps is 0, it is proved that the end point is reached, and the interpolation operation is stopped. This new successive approximation method has good interpolation speed and uniformity and is more accurate and faster than traditional point-by-point comparison methods and has certain application value.

3.3 Stepper Control System

The control system has designed a coordinate mechanical structure to realize the adjustment of the position of the filling head in the plane: the stepper motor is used in the x-axis direction to realize the adjustment of the landscape position of the device, and the y-axis direction is used to adjust the longitudinal position of the device. The stepper motor hardware circuit is shown in Figure 5.

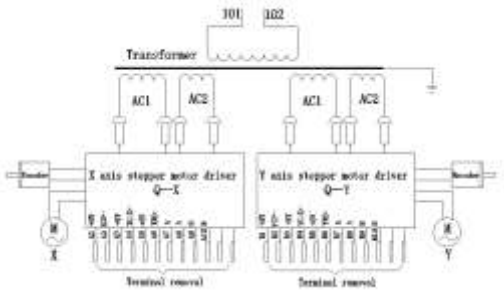

Figure 5: Stepper motor control system wiring diagram

3.4 Measurement Management System

The PLC communicates with the measurement weighing instrument TR700 via the MODBUS RTU. The PLC converts the received weight value into a decimal number through a data conversion instruction and stores it in comparison with the set reference quantity (maximum is 197 kg). PLC determines whether the current weight is greater than, less than, or equal to the reference quantity based on the comparison result. Then control the size of the flow conversion until the completion of quantitative filling automatic control. The system structure diagram is shown in Figure 6.

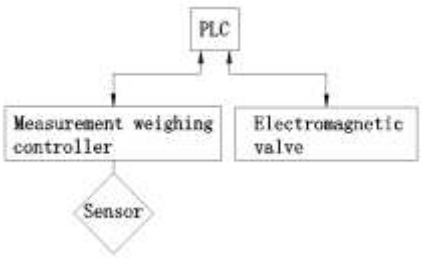

Figure 6: Quantitative weighing system structure

4. SYSTEM SOFTWARE DESIGN

The system program control adopts Siemens S7-300 series PLC. The flow chart of system software structure is shown in Figure 7.

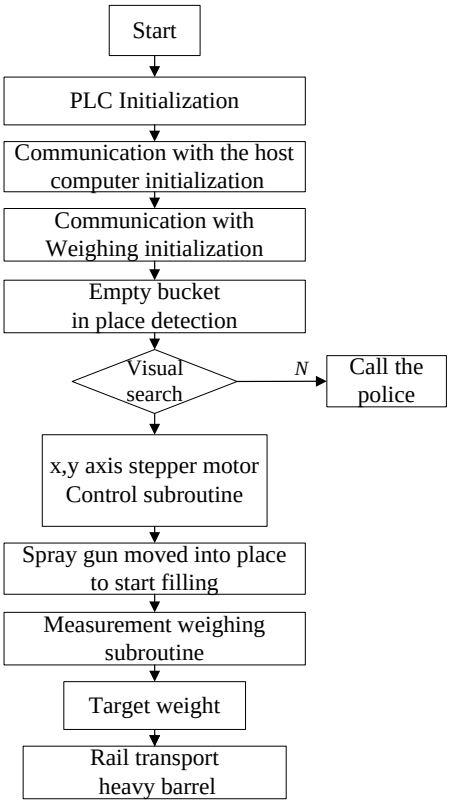

Figure 7: Software structure flow chart

5. CONCLUSION

The design of the control system mainly adopts the combination of stepping motor control and machine vision addressing, measurement and weighing control and S7-300 series PLC program control combined control method, which affects the reliable operation of the system data key bucket coordinates and barrels The MODBUS RTU communication is adopted for the measurement value, which makes the data transmission more accurate, avoids the external interference factors of the analog signal transmission, meets the requirements of the alcohol ether filling. The system has the advantages of convenient operation, accurate capacity, stable system, and high working efficiency.

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