Design of Electrical Assembly Line Device for Motor Shell Processing Using PLC

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Abstract. In order to solve the problem of low automation of small-volume production of aluminium motor shells, an automated production assembly line is designed. The device is controlled by three PLCs for cutting, expanding, and punching. The MCGS designed touch screen implements modification of parameter settings, management of various sections, and monitoring of the entire device operating status. The system debugging results show that the device can complete the full-automatic production of motor shells processing process. The device is convenient for workers to operate the control system, and has the advantages of high automation degree, good stability, less labor and high efficiency.

Keywords: Motor shell, assembly line, device, PLC.

1. Introduction

Motor shell materials used in industrial and agricultural production are mostly aluminum or aluminum alloy, and their sizes and thicknesses are different, which brings difficulties to mass manufacturing and processing. At present, the motor shell processing production line has a low degree of automation, a large number of manual operations are involved in the production process, and the workload is huge and there is a certain degree of danger. The cutting, expanding and punching of aluminum tubes in the production is mostly done by mechanical cutting machines, expanding machines, and punching machines, which are completed by workers operating machine tools. The whole process is manually operated by workers, the workload is very heavy, and there is a certain degree of safety hazards. The cutting edge is prone to burrs, and it needs to be polished by hand. The effect of hole expansion depends entirely on visual judgment and work experience. The accuracy of the aluminum tube produced cannot be ensured [1, 2]. For this reason, it is necessary to design a small automated production line for motor shell processing that can adjust processing parameters to meet the diverse needs of users, improve processing accuracy, and reduce costs [3].

2. Structure design of motor shell processing assembly line device

2.1. Analysis of processing technology of motor shell

The overall processing technology of aluminum motor shell is divided into three sections: cutting, expanding and punching. The length of the raw material of aluminum tube is generally at least ten
meters, and the length of the motor shell to be manufactured is 20~40cm, so it is necessary to cut the raw material of aluminum tube. After the long aluminum tube is fed by the cutting section of the assembly line, it is cut as required. The inner diameter of the cut aluminum pipe is smaller than the specification requirement, and the hole has to be expanded. In the expanding hole section, the expanding machine expands the inner diameter of the aluminum pipe to the required radius. A hole needs to be left on the motor shell to connect the external wires to the built-in motor. So a punching machine is needed to punch the aluminum tube. In the punching section, the punching machine punches holes in the aluminum tube to leave wiring holes to obtain the required motor shell. Depending on the technological requirements of the motor shell processing, the fully automatic motor shell processing assembly line device designed in this paper includes three parts: a cutting module, a hole expansion module, and a punching module.

2.2. Cutting module
The cutting module is composed of a rotary encoder, a stepper motor, a conveyor belt, a holder, a rotating motor, and a laser cutting head. The schematic diagram of the structure is given in Fig. 1. To measure the length of the feed, the rotary encoder is fitted on the stepper motor. It controls the stepper motor to drive the conveyor belt to perform the feeding operation. The conveyor belt is fitted with a retainer at the discharge end to prevent the aluminum tube from moving during cutting and pushing. The other end of the device is equipped with a laser drill bit, which is fixed on the connecting crank and driven by a rotating motor, which can rotate 360 around the aluminum tube raw material as the axis. The laser has good directionality, high brightness, fast laser cutting speed, high precision, smooth cut, material savings, low processing cost, and has many excellent characteristics that conventional mechanical cutting methods do not have. Therefore, this device chooses laser cutter for cutting operating.

2.3. Expanding hole module and punching module
The hole expansion module is composed of the position sensor, 1# manipulator, hole expansion machine, and 2# manipulator. The schematic diagram of the structure is shown in Fig. 2. The cut aluminum tube is sent by the conveyor belt to the position sensor and then sends signal. When the 1# manipulator places the aluminum tube directly above the hole expander, the aluminum tube is put on the hole expander, and the aluminum tube is loosened. The hole expander is operated according to the inner diameter of the expansion hole required by the design requirements. The cone is driven upward by the hydraulic device to push the surrounding telescopic cylinder to expand outward, and stop for a few seconds according to the preset parameters. After the hole expansion is completed, the hole expander returns Shrink, 2# manipulator takes out the aluminum tube after the expansion hole, rotates.
the aluminum tube after the expansion hole at a preset angle, releases the manipulator and returns to the initial position.

The punching module is composed of a position sensor, a 3# manipulator, a punching machine, and a 4# manipulator. The schematic diagram of the structure is similar to Figure 2. After the expanded aluminum tube is transferred to the position sensor by the conveyor belt, 3# manipulator grabs the aluminum tube and places it on the fixed base of the punching machine. The base can rotate and drives the aluminum tube to rotate until the aluminum tube is aligned with the punching machine. The machine carries out the punching operation, after the punching is completed, the 4# manipulator grabs the processed aluminum tube and discharges the material.

3. Design of control system of motor shell processing assembly line device

In order to realize the automatic assembly line production process, stepper motors, fixed cylinders, manipulators, laser cutters, expanding hole machines, and punching machines must complete a series of operations under the control of the controller. The cutting module, hole expanding module, and punching module in this device are respectively controlled by a PLC, and then a touch screen of the upper computer realizes the overall control and display. The control system structure is shown in Fig. 3 [4, 5].

![Figure 2. Schematic diagram of expansion module structure.](image)

**Figure 2.** Schematic diagram of expansion module structure.

![Figure 3. Structure diagram of control system of motor shell processing.](image)

**Figure 3.** Structure diagram of control system of motor shell processing.

3.1. **PLC selection**

In this control system, there are fewer control points and monitoring points, and the structure is relatively simple. However, this production line is designed with high-power mechanical actions such as cutting and transmission, which require high system reliability and safety. Therefore, PLC chooses 3 One SIMATIC S7-1200.

3.2. **PLC1 cutting system design**

The PLC1 system is used to control the operation of the laser cutting section, complete the stepper motor drive, start the laser cutter, and is responsible for the start and stop instructions of the entire program.
Fig. 4(a) is a schematic diagram of the hardware wiring of the cutting module control system, and Fig. 4(b) is a flowchart of the PLC1 software.

![Diagram of hardware wiring](a) Schematic diagram of hardware wiring.  
![Flowchart of PLC1 software](b) PLC1 software flow chart.

**Figure 4.** (a) (b) Cutting module control system diagram.

### 3.3. PLC2 expansion holes system designs

In the hole expanding system, PLC2 controls the mechanical claw 1# and mechanical claw 2#, as well as the hydraulic part of the expanding machine, to complete the feeding and discharging of the expanding machine. Fig. 5(a) is a schematic diagram of the hardware wiring of the expansion hole module control system, and Fig. 5(b) is the PLC2 software flow chart.
3.4. **PLC3 Punching system design**

The punching module completes the 3# manipulator feeding and the 4# manipulator discharging, as well as the control of the punching machine part. Fig. 6(a) is a schematic diagram of the hardware wiring of the punching module control system. Fig. 6(b) is the PLC3 software flow chart.

![Diagram](image)

**Figure 6.** (a) (b) Control system diagram of punching module.

3.5. **Electrical cabinet design**

Because this device uses PLC to control the automatic control system of the production line, it is necessary in order to design the electrical cabinet circuit, including the main circuit wiring diagram, stepper motor drive wiring, and the corresponding leakage protection switch and other supporting facilities. The speed regulating motor is used to drive the conveyor belt. PLC output is only 24V, the current is very small, and the large current output needs to be controlled by a relay.

4. **Configuration designs of touch screen of upper computer and system debugging**

4.1. **Configuration designs of touch screen of upper computer**

The configuration designs of the touch screen of the upper computer controls the operation of the three PLCs, which are convenient for the staff to set the control parameters, operate the switches and detect the working status. This device selects Kunlun Tongtai TPC1162Hi embedded integrated touch screen, and uses MCGS configuration for device interface design. Configuration design includes the establishment of system communication, system operation screen, and system parameter setting. For displaying the overall device and each section, the operation screen includes the real-time working status, start and stop buttons; the system parameter setting interface includes setting the running time and design specifications of the actuator.

4.2. **System debugging**
Firstly, PLC, touch screen and configuration are communicated, and simulation parameters are set for the process. You can switch to the control window to run the program at any time and observe the working status of each section of the window. Fig. 7(a) shows the working status of the overall device at a certain time, and Fig. 7(b) shows the operating status of the control window. The debugging results show that the designed motor shell processing assembly line device can complete the fully automatic motor shell processing production process.

(a) Overall device operation interface.
5. Conclusions
This paper designs a set of automated production lines to solve the problem of low automation in the small batch production of aluminum motor shell. It has the following advantages.

1. The motor shell processing assembly line device based PLC adopts laser cutting technology, which avoids the loss of raw materials caused by mechanical cutting and redundant secondary processing steps including leveling, grinding and polishing, saving raw materials and improving working efficiency.

2. The device completes a fully automated processing flow, improves work efficiency and processing accuracy, and increases safety.

3. Using the upper computer configuration design, process monitoring can be realized.

Acknowledgments
This work was financially supported by Innovation Training Program of Jiangsu Province for College Students (No. S202010320067). The corresponding author of this paper is Cairong Zhang.

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