Research on Automatic Control Mode of Profile Cutting Machine Based on PLC

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Abstract: Aiming at the constant need of cutting various metal profiles in industry, the control mode of automatic profile cutting machine is studied, which is based on PLC (Programmable Logic Controller) controller. MCGS (Monitor and Control Generated System) is used for monitoring and management, and the modular design of control layer is completed. The core of the control layer is that we have a cutting material database, which makes up for the fact that the current cutting machine control system only aims at a single cutting model or material, and the cutting speed and torque of the cutting machine need to be adjusted or designed manually. Based on this market demand, the automatic control mode of profile cutting machine based on PLC is established. Practice shows that this mode is based on the analysis and comparison of common cutting materials in the market, and the material database is consequently established. Users can choose the required cutting mode through the intuitive MCGS graphical interface, which improves the cutting efficiency of users and reduces the development cost of enterprises.

1. Raising of Issues

In recent years, the profile cutting machine is developing towards flexibility, modularization and automation. Automatic material feeding and cutting machine system is widely used in manufacturing production or real life, which is very representative. The cutting speed and efficiency of various industrial and living materials need to be closely related to the materials to be cut, and there needs to be a corresponding change in the selection of control mode and the design of program. The material to be cut and the length of the cutting target are uncertain in the cutting process. For this reason, concerning the operation of HMI (Human Machine Interface), we should focus on a friendly operation interface for the operator to modify and set, as well as how to compensate and correct the loss in the cutting process. In the processing and manufacturing process of aluminum alloy doors and windows in Foshan, Pearl River Delta area, the double-head saws, single-head saws, automatic material feeding cutting saws, corner saws and other equipment need to be designed for cutting control. In the automatic materials cutting process, there is a production line composed of automatic conveying devices. It is a production system with complex technology and high automation, which is managed by computer and combined with various control mode. It can help enterprises to reduce production costs, improve product quality, shorten product update timing and finally reflect on the improvement of enterprise competitiveness. The flexible automatic production line is based on hardware and supported by software. According to the materials to be processed and cut, the required control can be realized adaptively by changing the program database, so it is flexible and easy to be adjusted. It has realized
the flexibility and high efficiency of the manufacturing process, which is suitable for multi-variety, medium and small batch automatic cutting production. The electric control equipment does not need to be changed, only the control mode and other related parameters need to be changed.

2. Related Research and Discussion

2.1 Improve and Enhance through Mechanical Structure
In view of the frequent failures of automatic cutting machines and semi-automatic cutting machines at present, this paper puts forward some improvements and perfection in mechanical structure, as well as solutions for improving electrical control methods, canceling the position control mechanism, adding a timing control circuit based on a time relay, and optimizing and improving the structure.

The mechanical structure circuit with self retraction function is used to replace the existing position control mechanism, so as to reduce the damage of the cutting machine and the waste products produced in the cutting process.

2.2 Improve and Enhance through Electrical Design
The change of mechanical structure often affects the change of electrical circuit. In order to reduce the difficulty of design, the control electrical hardware with PLC as the core should be matched accordingly. When the cutting machine starts cutting, it inputs signals through relevant sensors to monitor the actions and data of the cutting process. The processing and cutting process of a single product is relatively stable and reliable, but it can not flexibly adapt to the change of materials and cause the change of control. The electrical control circuit often needs to be adjusted and changed to adapt to the change of the cut material.

3. The Establishment of Automatic Control Mode of Profile Cutting Machine Based on PLC

3.1 The Theoretical Analysis of Mode Establishment
Automatic control of profile cutting machine needs to suit different materials such as special-shaped aluminum, aluminum alloy, copper, nonmetal plastic and carbon fiber, especially aluminum doors and windows, plastic steel, aluminum extrusion, paper tubes and profiles; to realize cutting of single piece of multiple pieces; to realize 90°straight cutting, or 90°-45°left or right oblique cutting, etc.; and the cutting of metal square flat pipes, square flat steel, I-beams, channel steel, carbon steel, round pipes and other materials. However, in many current applications, these are customized development for their own products, without forming a database.

Automatic control mode is a balanced self-adaptive system based on PLC (Programmable Logic Controller) and supported by cutting material database. A dynamic database is built according to the hardness, density, thickness, length and other characteristics of commonly processed materials such as aluminum, copper and plastic. This database is open and can be continuously supplemented and improved as needed. At the same time, it corresponds to the corresponding auxiliary function feeding and main function cutting control program mode, so as to adaptively control the rotating speed and output power of the cutting motor.

3.2 The Establishment of the Mode
The mode is a theoretical and simple form of reappearing reality. The automatic control mode of profile cutting machine needs the support of material science, electrical engineering, PLC technology, database application and network technology, as well as processing technology analysis, control demand analysis and design, overall coordinated control, etc.

3.2.1 Analysis Control of Demand
(1) Material Feeding part: Controlled by the stepping motor, put the cutting material in place, press it to start, firstly, the electromagnetic valve acts to clamp the cutting material, and then according to the
set value (characteristics of the cut material), the system will process (the database calls out the corresponding control instruction) and then drive the stepping motor to convey the material to be cut.

2) Cutting part: When the length of the material to be cut reaches the set value, it will lower the shield to prevent the metal from splashing and hurting people during cutting, and then start the motor to cut.

3.2.2 Control Requirements
(1) Operations such as debugging and testing, setting parameters, starting and stopping, inching and feeding, etc. can be performed through HMI.
(2) The operator places the material on the workbench before starting, presses it “Start” once, and the electromagnetic valve at the back end clamps the material and feeds it.
(3) The motor delivers the material to a certain position, the front electromagnetic valve clamps the delivered material, the shield descends, the cutting motor is started for material head trimming, and the trimming distance can be set.
(4) After the trimming process is completed, the front electromagnetic valve, shield and cutting motor are stopped and restored.
(5) Press the start button again, and the material feeding motor will feed and cut.
(6) When the cutting of raw materials is completed or not enough for the next cutting, the motor will automatically stop running this time and display the information such as cutting completion on the HMI.
(7) There should be a pause function, which is convenient for the operator to pause to sort out materials or check the cutting opening.
(8) Emergency stop function: in case of emergency, press the emergency stop, all motors and solenoid valves will stop running, and the alarm will sound.
(9) Reset function, which restores the motor and solenoid valve or cylinder to their original positions and waits for the next start.

3.2.3 The Overall Design of the Mode
The general structure of automatic control mode of profile cutting machine is shown in Figure 1. The given values of feeding operation position and speed are input by HMI, and the feeding times are calculated by PLC.

![](Figure 1 General Structure of Automatic Control Mode of Profile Cutting Machine)

3.2.4 Hardware Configuration Design
Mitsubishi PLC is selected as the control software, and GX Works2 is opened for project establishment. Left click on “Project”-> “New” in the menu bar to pop up the dialog box below. Selected “series”: FXCPU, machine model: FX3U/FX3UC, engineering type: simple engineering, programming language: ladder diagram. As shown in Figure 2.
3.2.5 Communication Settings at Programming Port

(1) After creating or opening a project, click the “Connection Target” tab in the “Navigation” window.

(2) Find “Connection 1” in “Current Connection Target” or “All Connection Targets” and double-click to open it.

(3) Double-click the hyperlink text “serial usb” in the pop-up dialog box of connection target setting.

(4) In the pop-up dialog box for detailed setting of I/F serial on computer side, as shown in Figure 3 of serial setting. “COM Port” selects the serial port number of the connection between the current computer and PLC; “Transmission Speed”: select 115.2kbps; “Data Bit”: 7; “Odd-even Check”: even number; “Stop Bit”: 1

(5) Then click Communication Test, and subsequent operations can be carried out after the communication test is qualified.

3.2.6 Stepping Motor Drive Settings

(1) Stepping Motor Subdivision Table 1, which is the parameter setting of control precision.

| DIP1 | DIP2 | DIP3 | Subdivision       |
|------|------|------|-------------------|
| ON   | ON   | ON   | 400 Steps/Revolution |
| ON   | ON   | OFF  | 500 Steps/Revolution  |
(2) Stepping Motor Current Output Table 2, which is the setting of the output function of the control motor.

| DIP5 | DIP6 | DIP7 | DIP8 | Output Current |
|------|------|------|------|----------------|
| OFF  | OFF  | OFF  | OFF  | 3.0A           |
| OFF  | OFF  | OFF  | ON   | 4.0A           |
| OFF  | OFF  | ON   | ON   | 4.6A           |
| OFF  | ON   | ON   | ON   | 5.2A           |
| ON   | ON   | ON   | ON   | 5.8A           |

(3) Parameter Setting (set according to the database instruction)
Adjust the stepping motor driver subdivision to 5000 Steps/Revolution, and the dial-up code is as follows:
Dial-up code: DIP1: OFF; DIP2: OFF; DIP3: ON.
In order to make the output current of stepper motor driver consistent with or similar to the rated current of motor, 5.2A is selected in this case, and the dial-up code is as follows:
Dial-up code: DIP5: OFF; DIP6: ON; DIP7: ON; DIP8: ON.

3.2.7 Automatic Control Design of PLC Control Profile Cutting Machine
(1) The material head trimming program design is shown in Figure 4.

![Figure 4 material head trimming Program](image-url)
3.2.8 HMI Control Database Design

HMI interactive screen design is a very important part to make users feel more convenient, quick and friendly when using cutting operation. We need to debug-->use-->re-debug-->re-use in the process of user debugging and trial use so as to make the user interface more friendly. Thus we have designed the operation function interface of cutting machine, processing stroke, multi-stage setting, manual setting, IO (input and output) monitoring and so on. Figure 5 is the operation function interface of cutting machine, and Figure 6 is the user interface of cutting machine processing database.

![Figure 5 Operating Function Interface of Cutting Machine](image1)

![Figure 6 Processing Database Interface of Cutting Machine](image2)
3.2.9 Running and Debugging
(1) Enter the manual debugging mode, and jog the inching buttons such as material feeding and returning of stepping motor to check whether the action is correct.
(2) Put in the material, press the button to start, and observe whether the material head trimming is normal, and whether it is stopped after the trimming.
(3) Press the start button again to see if the feeding length of stepping motor is consistent with the set length.
(4) Open the program to monitor and further observe whether the feeding length and speed meet the requirements.
(5) Press the pause button and observe whether the feeding stops.
(6) Press the emergency stop button, the motor stops and the electromagnetic valve for clamping material is not released.
(7) Release the emergency stop to see whether all actions are reset.

4. Conclusions
Guided by the advanced automatic control theory, this research draws the following conclusions through research and practice: Through theoretical analysis, the inherent compatibility of automatic control mode of profile cutting machine and the process of mode demand are put forward; The automatic control mode of profile cutting machine based on PLC is established. The effectiveness of the mode is verified by application, which is mainly reflected in the self-adaptive control program matching with cutting materials. Further more, the operation method, steps and mode selection are put forward, which can help enterprises reduce production costs, improve product quality, shorten product update timing, and finally reflect on the improvement of enterprise competitiveness. The innovation of this research lies in revealing profoundly that the control of profile cutting machine can be multi-mode and interconnected. Establishing enough material database can effectively improve the cutting production efficiency of enterprises, and finally promote the self-growth of automatic control targets of cutting machines.

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