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# Application of automatic control technology of drilling machine based on PLC

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**Abstract.** At present, the rocker shaft produced by combined drilling machine is still in the condition of small quantity supply, which has the problems of low production efficiency and high processing cost. In order to solve these problems, in this paper, a variety of composite components were selected to formulate I/O point table and design the PLC control system that can meet the requirements through the analysis of the control requirements of modular machine tools, and the PLC program was written. After the control combination completed a process, the rotary table scale division was controlled, and then the next process was completed, until all processing was completed. The final experimental results proved the feasibility of PLC advanced control technology in modular machine tools. In addition, this technology can realize automatic production and solve the problems of low production efficiency and high processing cost.

**Key words.** Combination drilling machine, PLC control technology, multi station.

## 1. Introduction

With the advent of industry 4.0, the level of automation and intelligence is getting higher and higher. As the pillar industry of the national economy, the automobile industry is the benchmark of advanced technology. However, China is only a big country in automobile manufacturing, not a powerful country, and lacks in its own intellectual property rights and innovative capabilities. Therefore, the development of advanced manufacturing technology is a requirement for the new normal state of industrial transformation and upgrading, and it is a dream of a new generation of auto makers. The auto parts industry is an important part of the automobile industry chain, which provides the standardized, universal and serialized components for the automobile factory. At present, China's manufacturing industry is facing a situation that: high-end manufacturing industry of Europe and the United States in China appears reflux, and the low-end manufacturing industry moves to Southeast Asia, at the same time, the aging of the population makes the enterprises in China

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with backward traditional machinery and equipment pay a high cost to recruit labor. Facing the trend of the reduction of population bonus, China is at the cusp of technological transformation and upgrading. It is the theme of the times to develop new high technology and cultivate the creative talents. And along with the world economic downturn, the revival of manufacturing will lead to economic growth. Now, many private machinery processing enterprises have personally felt such recruitment difficult pain. They are trying to reduce the reliance on labor through equipment modification or the introduction of highly automated equipment to meet mechanized production.

## 2. State of the art

As the preferred product of discrete control, PLC developed rapidly from 1980s to 1990s. The worldwide annual growth rate of PLC controllers was maintained at 20∼30 % [1]. With the continuous improvement of factory automation and the expansion of PLC controller market capacity base, the growth rate of PLC in industrial developed countries has slowed down in recent years. However, the PLC growth in China and other developing countries is very rapid [2]. According to the comprehensive information, the world's PLC sales revenue in 2004 was about $10 billion, which occupied a very important position in the field of automation. The PLC controller is developed by imitating the principle of the original relay control. In 1970s, the PLC controller had only on-off logic control, and the first application was the automobile manufacturing industry [3]. It uses storage, execution, logical operations, sequential control, timing, counting, and arithmetic operations, and controls all kinds of machinery or production process through the digital input and output operation. The user's control program expresses the process requirements of the production process, which is stored in the user program memory of the PLC controller [4]. The operation is executed one by one according to the contents of the stored program to complete the operation of the process. In the past 10 years, with the continuous decrease of the price of PLC controller and the expansion of user's demand, more and more small and medium-sized equipment has begun to adopt PLC controller to control, and the application of PLC controller in our country has been increasing very fast [5]. With the rapid development of China's economy and the continuous improvement of the basic automation level, the PLC controller will maintain high growth momentum for a period of time.

## 3. Methodology

The main movement of combination drilling machine is the rotational movement of the cutter, and the feed motion is the axial movement of the cutter and the indexing movement of NC rotary table [6]. The schematic diagram of drilling a hole is shown in Fig.1. The speed of the power head is controlled by adjusting the hydraulic damper of the pneumatic power head.

PLC technology is used to control the rotary table and pneumatic power head,

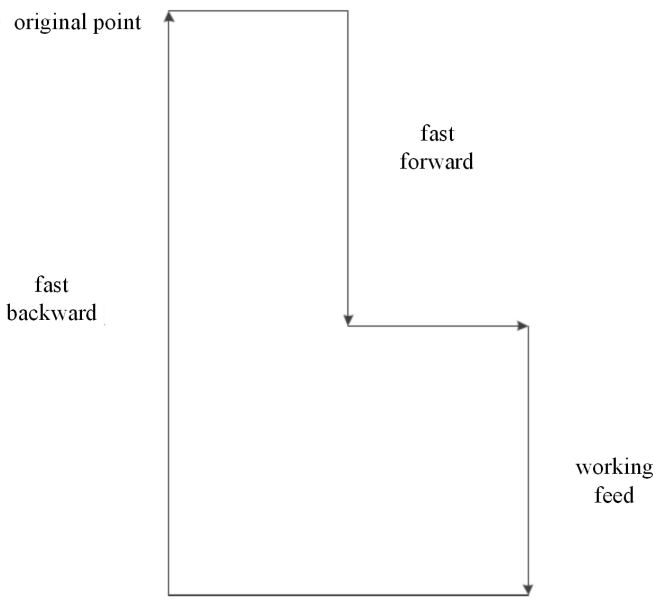


Fig. 1. Sketch map of drilling motion

so as to complete the workpiece processing. After each process, the workpiece completes automatically indexing rotation to the next working position [7]. Combination drilling machine needs 10 divisions to finish a rocker shaft processing. Control requirements in machining are as follows. The main movement is driven by a three-phase AC asynchronous motor, which turns forward and does not change speed. The stroke of the feed motion is controlled by the travel switch. The transposition of the workpiece is controlled by the indexing of the rotary table. The clamping and releasing of the workpiece is realized by pneumatic device. All actuating elements are controlled by the PLC [8]. The machining position of the combination machine tool is shown in Fig. 2.

The working process of the equipment: After the system is started, the three-phase asynchronous motor action of the pneumatic power head realizes the rotation of the main movement of the cutter. Meanwhile, the cylinder action of the power head is fast forward. When the hydraulic damper touches the iron block to move forward, it achieves rewind after processing. After the tool is pulled out of the upper limit of the workpiece, the slewing table is shifted with 36 degrees, and the second order is processed. In turn, reciprocal cycles are conducted [9].

Motion control system is mainly composed of motion controller, electrical servo mechanism, mechanical device and detection device. The block diagram of the system is shown in Fig. 3.

The operating panel is the part used by field operators to provide a complete interface between the control system and the operator. The electric servo mechanism is the control motor. AC servo motors are often used in the servo system of mechatronic equipment. Because AC servo motor adopts detecting device to realize

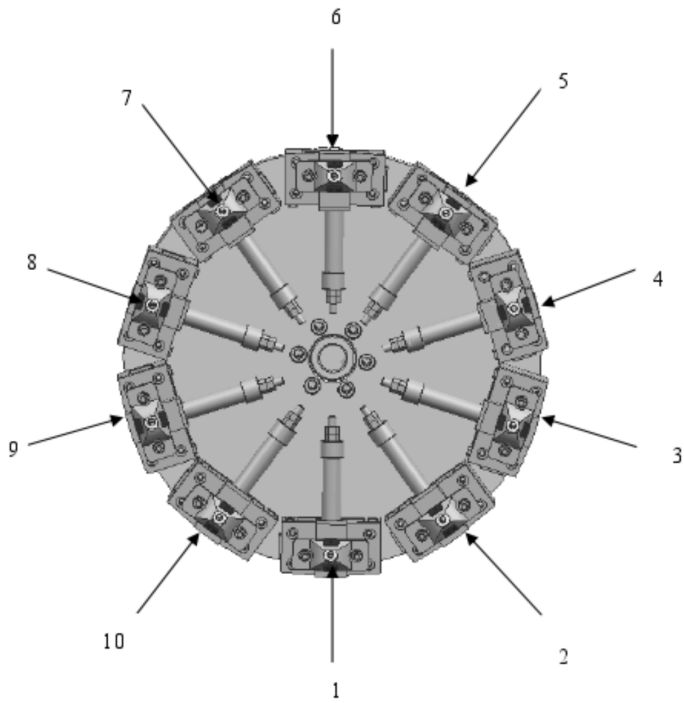


Fig. 2. 1–No.1 position; 2–No.2 position; 3–No.3 position; 4–No.4 position; 5–No.5 position; 6–No.6 position; 7–No.7 position; 8–No.8 position; 9–No.9 position; 10–No.10 position

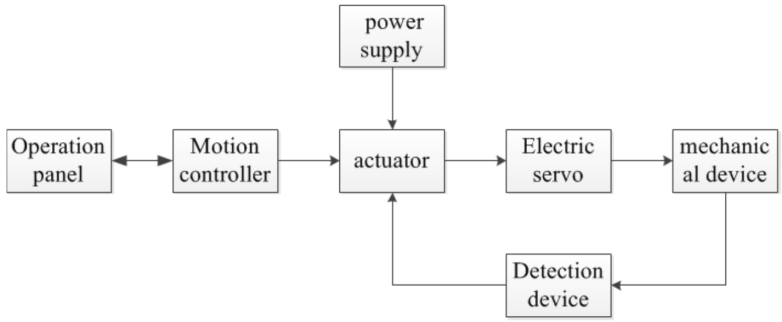


Fig. 3. System diagram

closed loop control, the precision is very high. In order to ensure that the control mechanism has the accurate location of the origin, the servo motor has the advantage in the precision range [10]. For normal operation, servo drive must be the functions as follows. First, it receives control signals, such as position and speed of the controller, and processes them. The servo motor is driven by the processed signal and operates at a certain speed. The second is to receive signals or other displacement signals from the encoder of the servo motor to determine the rotation speed and

displacement of the servo motor, so as to form a speed closed loop or a position closed loop control [11]. The combination parameters of the BCH servo motor and the Leximm2323Plus driver of the rotary table are shown in Table 1.

Table 1. Combination parameters

| BCH Servo motor output power (KW) | Rated torque (NM) | Peak to stop torque (NM) | Maximum mechanical speed (rpm) | Rated speed (rpm) | Type of servo driver | Type of servo motor |
|---|---|---|---|---|---|---|
| 4.5 | 28.26 | 71.62 | 3000 | 2000 | LXM23-U45M3X | BCH1803M21C |

In the I/O servo drive position control mode of operation, Lexium 23 servo drives the pulse train to position control through the controller, which is also compatible with high differential multi pulse input. The PTO PLC generator outputs high speed pulses through digital output points Q0.0 and Q0.1 [12]. Here, we use the PLC Q0.1 output terminal as the digital output of the PTO generator, and the Q0.1 will not have other digital output functions.

The hardware of the electrical system includes sensors, cylinders and solenoid valves.

A sensor is a detection device. Its working principle is that it can be sensitive to the information of the measured object, and convert the detected signal source into electrical signals or other forms of signal output according to the specific rules, so as to achieve the requirements of information transmission, processing, display, record and control [13]. Sensors include electrochemical sensors, electrical sensors, resistance sensors, temperature sensors, displacement sensors, and pressure sensors [9]. In the combination drilling machine control system, the main sensor switches the amount of power to the electrical signal to the PLC, which serves as a basis for the judgment of the PLC control system CPU. Each pneumatic power head has two proximity switch sensors as signal bits for resetting and cutting. Proximity switch sensor adopts small square proximity sensor KJT-Y8S. The inductance proximity switch is composed of a LC high frequency oscillator and an amplifying circuit. It uses metal objects to produce eddy currents in the object near the oscillating induction head that generates electromagnetic fields. This vortex reacts on the proximity switch, oscillating capability is weak, and internal circuit parameters change. Thus, it is recognized that whether the metal object is approaching, thus controlling the on-off of the switch.

The cylinder transforms the pressure energy of the compressed air into mechanical energy, and the drive mechanism acts as a linear reciprocating motion, rotation, or swing motion [14]. Solenoid valve is an electromagnetic control of industrial equipment, which is an automatic basic component for controlling fluids. It is an actuating element that adjusts the direction, flow, speed, and other parameters of the medium. The gas source is connected by the main air pipe through the triple parts (air filter, pressure reducing valve, and oil sprayer), the electromagnetic valve

and one-way throttle valve to the actuating cylinder. No.1 pneumatic power head cylinder turns on the positive coil by reversing the two-sit five-pass (double control solenoid valve), and the positive air path is connected (positive movement makes air in stoma). Even if the positive action coil is switched off, the positive air path is still connected and will remain until the reverse action coil is energized. If the reverse action coil is energized, the reverse action gas circuit will be switched on (reverse movement makes air in stoma). Even if the reverse action coil is switched off, the reverse action gas path is still connected and will remain until the positive action coil is energized. This is equivalent to "self-locking".

Based on the analysis of the combination drilling machine control system, we can get the following control program design method.

After the PLC is powered on, the hardware and software are initialized and scanned. It will read the input, execute the user program, and process the communication request. It automatically checks whether the firmware, program memory, and extension module work correctly and overwrites the output. If the program uses an interrupt program, an interrupt event will occur. CPU stops the normal scan and executes the interrupt program.

If the program uses the immediate I/O directive, the value of the I/O point can be read and written directly.

According to the I/O number estimation, storage capacity, control function and model type, we select SIEMENS S7-200 CPU 226; programming software is selected as: STEP 7-Micro/WIN.

According to the actual processing requirements, PLC system will be equipped with 3 modes of work: automatic mode, manual mode and return to the origin. The selector switches SA1 SA3 indicate the control of the mode of the automatic operation, manual operation, and return points operation. The selector switches SA4 SA10 mean switching the power head 1, the power head 2, the power head 3, the power head 4, the power head 5, the power head 6, and the power head 7 in manual operation. The oil pump push button switch and the oil pump button switch (SB1, SB2) are used to control the opening and disconnection of the oil pump motor, which provide power for the hydraulic system. The water pump push button switch and the water pump button switch (SB3, SB4) are used to control the opening and disconnection of the water pump motor, and provide power for the cooling system. The clamping and loosening button switches (SB5, SB6) are used to control the clamping and loosening of the two states in manual operation. A rotary push-button switch (SB8) is used to control the rotation of the rotary table. The start and stop button switches (SB9, SB10) are used to control the opening and stop of actions in manual mode, automatic mode, and return to origin mode. The power head starter and the power head stop button switch (SB11, SB12) are connected in series with the contact of the selector switch SA4 SA10 to control the starting and stopping of the power head in the manual operation mode. Load power and emergency stop button switch (SB13, SB14): Press the "load power" button so that the KM coil is electrically self-latching. The KM's main contact is switched on, and the AC power is supplied to the external load. In case of emergency, disconnect the power with the emergency stop button. Manual work is mainly to debug machine tools, and

test whether the working position can meet the actual processing requirements. It is easy to fine tune the position of the fixture and sensor.

The PLC control program consists of four parts, the main program, the public program, the manual program and the automatic program.

The main program can call various subroutines to facilitate the switching of various working modes.

Public programs are used to handle the switching conditions between tasks that are performed in different ways and different modes of work.

In the manual program, when the system is in manual operation, the control requirements are: the separate work and stop of 7 power head motors; the feed movement of fast forward, together forward and rewind of 7 power head motors as well as the clamping and loosening of the cylinder valve. Manual operation: press the "relax" button, the cylinder valve control fixture in a relaxed state, and we can manually put the upper part. After we have finished manually pressing the clamping button, the workpiece is clamped in the fixture. Press the power head start button, then the power head motor starts the spindle rotation. Then press the "start" button, the feed movement will begin to complete the fast forward, together forward, and rewind backward and stop in situ. At this time, control motor power off through the "power head stop". Then through the selection switch, adjust the required power station head motor to get power. Control the transposition by means of the "turn" button. This is done manually. The purpose of manual operation is to test the manufacturability of the system and test whether it can meet the process requirements. If there is a deviation, proper debugging is required.

An automatic program is a way of controlling the work of the system cycle. Automatic working mode mainly controls the automatic feeding, machining, indexing and feeding of the system. The automatic program describes the control process of the automatic program with the actions of the power head, the feeding mechanism and the No. 1 fixture.

## 4. Results analysis and discussion

In order to prove the feasibility of PLC control system, an example is given to verify the feasibility of the control system. A continuous flag bit M7.0 is set in the program, which is used as a continuous or stop conversion condition. The normally open contact of the start button is connected in series with the normally closed contact of the stop button. When the "start button" is pressed, the continuous flag M7.0 is ON, and the M7.0 coil remains self-locked, so as to cycle in cycles. When the stop button is pressed, the continuous flag bit M7.0 becomes OFF, and the system completes the cycle and stops at the initial step. Fig. 4 is the automatic program *a*.

When the cycle is stopped, the stop button is pressed to break the normally closed contact of the stop button switch. At this point, the successive flag bit M7.0 is reset to OFF. When M7.0 is OFF, the system reset the initial step M0.0 and performs the previous step of stopping the loop. M5.5, M5.6, M5.7, M6.0, M6.1, M6.2, M6.3 steps are reset, and the power head motors (Q1.1, Q1.2, Q1.3, Q1.4, Q1.5, Q1.6, and Q1.7) are reset. The system is in a stopped state. Fig. 5 depicts the

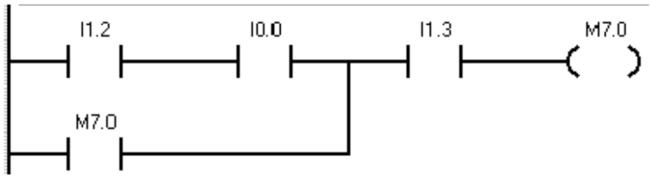


Fig. 4. Automatic program *a*

automatic program *b*.


Fig. 5. Automatic program *b*

Fixture cylinder clamping and relaxation of the cycle control requires that after feeding, the workpiece enters into the fixture and clamped the workpiece. The 10 clamp cylinder is also a cycle of clamping and releasing. When it is at the No.1 position, the feeding of the feeding mechanism is in place. The contact sensor I8.0 of the front limit sensor is ON, and the C1 counter is ON. The normally open contact of the C1 is ON, and it triggers the Q2.1 to ON and clamps the workpiece. When the normally closed contact M8.1 is broken (OFF), the Q2.1 is OFF. The cylinder is in a relaxed state, and the material ejecting mechanism ejects the workpiece. The other No.2 to 9 cylinders works in the same way, but the trigger conditions are different. The counter of No. 1 cylinder is triggered by the loosening of cylinder 1, and the Q2.1 is on the falling edge of OFF to trigger the reset of the counter. The No. 2 cylinder clamping Q2.2 is the rising edge of ON, the trigger circuit is disconnected to control the No. 1 cylinder Q2.1OFF to relax, and the workpiece is ejected into the clamp. Fig. 6 is the automatic program *c*.

The work processes are as follows. The process that workpiece is introduced from the charging mechanism is called feeding". The return of the finished material is called "feeding returns". The upward movement of the clamp cylinder is called "release". The downward movement of the clamp cylinder action is called "clamping". When feeding the material and the feeding mechanism triggers the "front limit" sensor, the switch quantity signal becomes ON, and the clamp cylinder is "tensioned". When the lower limit of the cylinder is triggered, the switch signal is changed to ON, and the feed mechanism cylinder is "returned". When the rear limit sensor is triggered, the rotary table is lifted. When the upper position sensor of the rotary worktable is triggered, the rotary table rotates 36 degrees. When the rotary

trigger rotary position sensor, power head start to fast forward, together forward and rewind. The projectile is used to trigger the loosening of the clamp cylinder by 10 counters, and then the ejection mechanism ejects the workpiece. With the set program, the system goes round and round until the "stop" button is pressed.

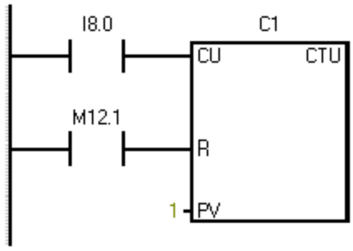


Fig. 6. Automatic program *c*

## 5. Conclusion

In order to solve the problems in actual production, the automatic drilling machine control technology based on PLC and its application were studied in this paper. The parts of the combination drilling machine were selected according to the requirements. Then through the formulation of the I/O point table, the PLC control system which could meet the requirements was designed. The practical verification was carried out to achieve theoretical linkage practice finally. Practical validation of the theoretical results demonstrated the feasibility of the PLC control system. Some conclusions were obtained as follows: in this paper, through the analysis of the control requirements of modular machine tools, a variety of composite components were selected to formulate I/O point table and design the PLC control system to meet the requirements. PLC's "automatic" mode of operation, "manual" mode of operation and "return to the origin" work were in line with the actual production needs. In the "manual" mode of work, the machine tools could be debugged, and the quality of product processing could be tested. In the "automatic" mode of work, the system can achieve periodic work. The "return to the origin" mode can provide initialization conditions for the "automatic" mode of operation. Although this paper has achieved good results, there are still some problems that need further study. For example, through the study of this paper, it can be seen that the design process of PLC control is tedious, and how to implement a more convenient PLC design is a key point of research in the future.

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