CHEMICAL ENGINEERING TRANSACTIONS
VOL. 62, 2017
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Fei Song, Haibo Wang, Fang He

ISBN 978-88-95608- 60-0; **ISSN** 2283-9216
DOI: 10.3303/CET1762198

PLC Electric Control System of CNC Machine Tool

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This paper studied the design of PLC electrical control system of CNC machine tool. The design program of the electrical control system is established according to the requirements. The parameters of all electrical components are determined through calculation of electric load for selection of electrical equipment and wires. Then the design of power supply and distribution of the electrical control system is described in detail, and the design of the electrical control system of main equipment is studied. This paper focuses on the design of spindle, feed axis and module. In addition, this paper summarized the design of the electrical control cabinet, wiring, installation and commissioning of electrical equipment, inspection of the machining effect after installation and the control system. The entire CNC machine tool electrical control system is designed.

1. Introduction

The electrical control method for CNC machine tool determines the performance of the control system. The machine tool is essentially an electromechanical energy conversion device, to convert electrical energy into mechanical energy for processing (Bonaccorsi et al., 2014). Therefore, the distribution and management of electrical energy is the guarantee for the machine, playing a role similar to the human heart. The machine tool electrical control system consists of the machine tool power supply and distribution system, the spindle control system, the feed axis control system, the cooling oil pump control system and other auxiliary equipment control systems (Gow et al., 2012). PLC is introduced to improve the electrical control, especially the electrical switch control. In this paper, PLC is mainly used to control the cooling motor, pump motor and other auxiliary electrical control systems. The reliability and flexibility of the system has been improved via replacing the relay-contactor control system with PLC, a qualitative leap has been achieved in control (Inglese et al., 2017). One key point in this paper is the function of automatic tool setting. In the past, the tool setting of CNC machine tool was time-consuming and labor-intensive but not accurate. With the automatic tool setting system, it was completed quickly and conveniently, reducing workload while improving efficiency and product accuracy (Kawada et al., 2012).

2. Scheme of electrical control system

2.1 Scheme of system

Figure 1 shows the overall program of electrical control of CNC machine tools. Take ARM9+μCEO S-II as the CNC main control system, DSP+FPGA as the core of motion controller and servo drive, and PLC for control of electrical auxiliary system (Khoshdarregi et al., 2014).

2.2 Requirements for control

(1) Spindle
Control of spindle motor start/stop, speed changing and regulation; stable spindle speed, fast acceleration/deceleration, low speed high torque and high overload capacity etc (Kumar et al., 2014).
(2) Feed axis
X, Y and Z axes is driven by a servo motor, controlling the speed and the angle of each axis. Accuracy: repeat positioning: ±0.005mm; positioning: ±0.001mm; fast: perfect acceleration/deceleration, smooth triaxial linkage, good tracking, average processing speed of 20cm/min and up to 1 m/min; stability: low vibration, high anti-interference ability etc (Liu et al., 2016).

Please cite this article as: Jinghai Han, 2017, Plc electric control system of cnc machine tool, Chemical Engineering Transactions, 62, 1183-1188 DOI:10.3303/CET1762198

(3) Auxiliary control: control of the hydraulic pump, lubrication motor, automatic tool setting, cooling pump motor, fan motor control (Lu et al., 2013).
(4) Emergency stop and work bench stopper.

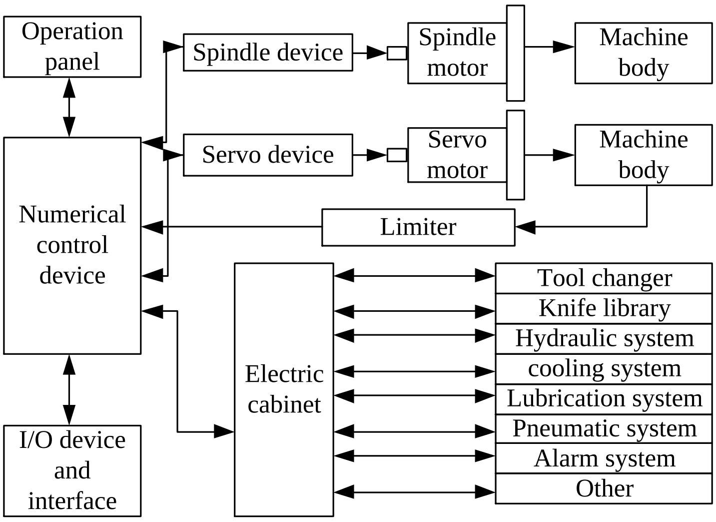

Figure 1: Block diagram of auxiliary electrical control system

3. Power supply and distribution of CNC machine tools

3.1 24V DC power supply

Two lines of 24V switching power supplies are used. One 24V switching power supplies CNC and the motion controller, including chips in each module. The other low power 24V switching power supplies only ARM, DSP, PLC and J24VPWR interface of IO module, and is not shared by other signal voltage (Olesen et al., 2012).
ARM power unit
DC24V-H power line (J24 VPWR interface) +24V 2-core 0.5 mm2 shielded 4-pin universal terminal (Figure 1).

Table 1: ARM power unit

Pin	1	2	3	4
Signal	GND	24V	None	Shielded wire
Color	Black	Red	None	Yellow green
Line code	E24V-H	P24V-H	None	PE

IO board
DC24V IO board power line and signal line (J24 VPWR/J24 VIO interface) + 24V 2-core 0.5 mm2 shielded 4-pin universal terminal (Figure 2).

Table 2: IO board

Pin	1	2	3	4
Signal	GND	24V	None	Shielded wire
Color	Black	Red	None	Yellow green
Line code	E24V-I/E24V	P24V-I/P24V	None	PE

3.2 Calculation of electric load and selection of wire

The electric load can refer to electrical equipment or the electrical unit, as well as the electrical power or current consumed by the electrical equipment or user (Pei et al., 2014). This paper refers to the electrical equipment and the electrical power and current consumed by equipment.
The wire here refers to the cabling between electrical equipment and power supply system or other electrical equipment. Select proper wire for different loads and methods to meet the requirements of safe, reliable and energy saving (Raskin et al., 2016).
(1) Calculation of electric load
Only some CNC machine tool electrical equipment are used in this paper with less electric power difference, so we calculate the electric load using the demand coefficient method (Rastorguev et al., 2013). The demand coefficient method is based on the power consumption of electrical equipment to calculate the load. The running system is analysed (Ripepi et al., 2012). The power equipment is grouped according to certain rule. The relationship between the equipment power and the calculated load are identified and the corresponding parameters are proposed, which are used to infer the load of a similar system to be built. The demand coefficient method is applied to the load calculation of the power equipment group with a large number of equipment and small power difference (Roy et al., 2012).
(2) Selection of wire
Stranded PVC (plastic sheath) copper wires are used for the electrical control system for CNC machine electrical equipment in general. Consider the following for selection of wires (Roy et al., 2015).
Select wire of proper section. Wire with large section will cause waste and is not beautiful, not easy to install; for wire with small section, the resistance is high, easy to cause overheat and damage to wire, and the electrical equipment cannot work properly (Tan and Cheng, 2013).
Select wire with large section as the starting line to reduce the voltage drop of the line and ensure large start-up current (Telnov, 2014). The average cross-section of wires for CNC machine electrical equipment is 0.75-1.50 mm2; the cross-section of wires for lighting systems and signal light system is 0.75-1.00 mm2; the cross-section of wires for armature, motor and relays is 2.5-5.0 mm2(Xia et al., 2014).

4. Electrical control system of main equipment

4.1 Electric control of feed axis

The rail feed axis features small contact surface with the body, low friction, low resistance and load capacity, suitable for cutting of light loads, e.g., machining of metal parts, auto parts and other products (Yan et al., 2013); The hard-rail feed axis features large contact surface, high friction, high resistance and load capacity, suitable for cutting of heavy loads, e.g., machining of molds (Zhou et al., 2014). This machine uses semi-linear rails, and the purpose is between the above two ones. The cutting requirements include those for feed axis and the spindle. The requirements on feed axis are:
(1) Accuracy: 1) repeat positioning: ±0.005mm; 2) positioning: ±0.001mm;
(2) High-speed: Good acceleration/deceleration, smooth triaxial linkage, good tracking. The average machining speed is 20cm/min and can reach 1m/min;
(3) Stability: low vibration, high anti-interference ability etc.

4.2 PLC unit

The Programmable Logic Controller (PLC) is used for automatic control of equipment. The PLC works in a cycle scan mode. The working process consists of three stages: input sampling, program execution and output update. The PLC is adopted in CNC machine tools, mainly for the periphery of machine tools, auxiliary electrical control, and also called PMC (programmable machine tool controller).
(1) External wiring of PLC
The lubrication system of auxiliary electrical control system has 2 inputs and 2 alarm outputs; The cooling system has 2 inputs and 2 alarm outputs; the automatic tool setting system has 6 inputs and 6 alarm outputs; The lighting and signaling system has 1 input and 4 outputs; the tool change system has 5 inputs and 5 outputs. There shall be 1/3 of the allowance for selection of PLC. We use HC-241 SMR PLC with 24 inputs and 15 outputs and scanning frequency up to 1000HZ, fully meeting the requirements.
(2) Lubrication and cooling control system
The lubrication and cooling system in the CNC machine tool electrical control system is improved and the operating conditions are monitored to ensure that the mechanical parts of the machine tool are well lubricated and cooled. The oil supply, cooling oil supply and cycle time can be adjusted according to the working status of the machine tool in order to save oil and cooling oil.

The electrical control principle of lubrication and cooling system includes the principle for motor control and that for overall control. The schematic diagram of motor control is as follows:

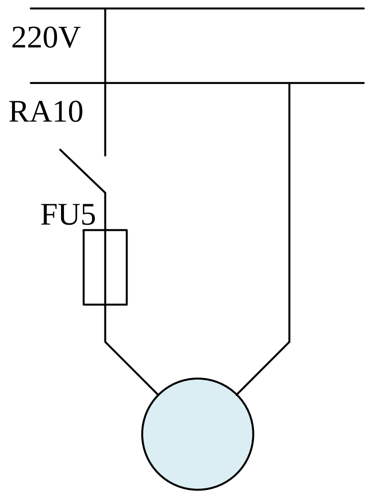

Figure 2: Lubrication pump motor

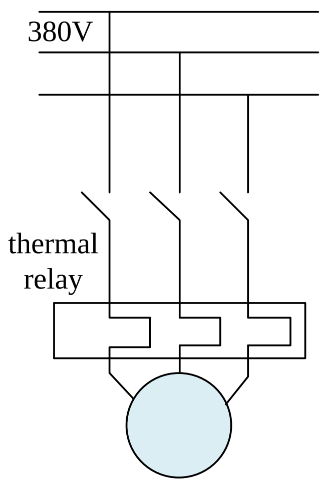

Figure 3: Cooling pump motor

Figure 4 shows the flow chart of automatic lubrication and cooling control. When the system is ready, the CNC sends a signal to start the lubrication system. After lubrication for 15s, the motor stops.
When the pressure switch is turned on, the timer starts (25min). After the timing ends, the pressure switch is turned off. The lubrication and cooling motor works for 15s and circulates. Set X7 to motor overload. Set X10 to cooling motor overload. Set X9 to low lubricant. Set X11 to low coolant. When any of these signals is ON, the system will send an alarm signal.

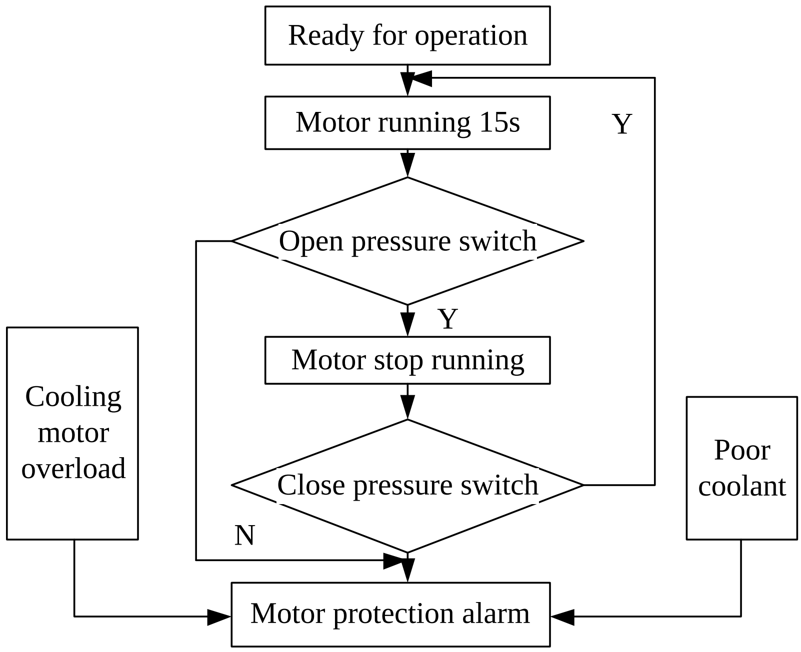

Figure 4: Flow chart of automatic lubrication and cooling control

5. Conclusion

In this paper, the electrical control system of CNC machine tools are researched and analysed. An electrical control system has been designed and installed to meet the requirements of high speed, high precision, high reliability and intelligence of CNC machine tool. The electrical control system of external electrical appliances is described on control of the spindle motor, X, Y and Z axes, as well as the system start-up, emergency stop and protection. The electrical control system of the main equipment is designed. The spindle motor control system, the feed axis motor control system, ON/OFF and stop of modules and the system are designed and discussed in detail. Finally, this paper designs the electrical control cabinet, including the layout of electrical control systems, installation, selection and wiring of electrical components. The precaution on debugging of the electric control system was given. The CNC machine tool processing effect using the electrical control system is described.

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