Research on Electrical Control System of CNC Machine Tool Based on Vector Control

Wei Zhang*, Qingsong Zhao, Jianzhi Tuo
Weifang Engineering Vocational College, Qingzhou, Shandong, 262500, China

*Corresponding author: 358199992@qq.com

Abstract. With the rapid development of science and technology, the society demands more and more diversification of products, which requires the cycle of product renewal to be shorter and shorter, which makes the proportion of multi-variety and small batch production increase obviously. CNC (Computer Numerical Control) machine tool is a very popular production machine in China's industrial production, which is mainly composed of hardware circuit, mechanical part and lower computer software. CNC machine tools play an important role in solving the problem of precision or complex parts, and the data of CNC machine tools in mechatronics system are typical. Numerical control technology is related to a country's position in international industry, so accelerating the development of advanced numerical control technology and strengthening the construction of numerical control equipment are important methods to improve a country's position in international industry. Based on vector control technology, this paper discusses the design of electrical control system of CNC machine tools, and studies the methods to improve the safety, reliability, machining accuracy and productivity of CNC machine tools, in order to provide reference for the further application of vector control in CNC machine tools.

Keywords: Numerical control machine tool; vector control; electrical control

1. Introduction
CNC machine tool is a kind of automatic machine tool with high precision and high efficiency, which has a typical mechatronics system. The traditional machine tool design process is controlled by relay, and its equipment independence is low [1]. As the carrier of advanced manufacturing technology, the development of CNC machine tools is closely related to the development of various fields, so the development trend of CNC machine tools has attracted much attention, and its reliability has become the key index of concern [2]. Manufacturing is not only an important cornerstone of human economic activities, but also the driving force of human historical development and civilization progress. The level of manufacturing industry is an important indicator of a country's Industrial Development [3]. Because the technology is not perfect, resulting in a lot of controller circuit structure is also very complex, high nursing cost, and it is easy to failure, so the traditional relay and contactor control scheme of machine tool is gradually eliminated [4]. In the process of developing the electrical control system of CNC machine tools based on vector control, we need to conduct a comprehensive analysis of the vector control system to further improve the system [5]. From the current development...
situation, the development of vector control system can reduce the cost, and use the electrical control system to control the operation of CNC machine tools, fundamentally avoid system accidents [6]. Electrical control and drive system is one of the key subsystems of CNC machine tools, and it is also the subsystem with the most frequent faults in each subsystem [7]. Therefore, improving the reliability of electrical control and drive system is of great significance to improve the reliability of CNC machine tools.

In the process of the continuous development of science and technology, vector control design is gradually introduced into the electrical control system of CNC machine tools, which effectively improves the system configuration of CNC machine tools. In the daily production process, plane positioning is used to realize micro hole drilling machine [8]. As the industrial foundation of a country, numerical control technology and numerical control device will directly affect the country's industrial development and industrial output value [9]. The application of vector control in CNC machine tools is the inevitable trend of machine tool development, which can not only improve the automation level of machine tools, but also improve the machining accuracy and controllability of machine tools [10]. CNC machine tools play a very important role in processing some precision parts, and the electrical control system of CNC machine tools based on vector control is an inevitable trend of the development of CNC technology [11]. The electrical system of CNC machine tool is designed on the basis of modularization. Both mechanical production and electrical control have been further improved, which effectively realizes the control of high-precision closed-loop state and improves the efficiency of processing [12]. The emergence of CNC machine tools can better solve the production problems of some complex and precise parts. The electrical control system of CNC machine tools using vector control is the inevitable trend of the development of CNC technology. This paper mainly discusses the electrical control technology and design method based on vector control, which has positive significance for ensuring the safety production of the whole machine tool and improving the production efficiency.

2. Overall design of electrical control system for CNC machine tools

2.1. Basic structure of CNC machine tools

The overall optimization scheme for electrical control of CNC machine tools uses ARM as the control system, vector control as the control center of electrical auxiliary system, and DSP as the servo drive core and motion controller. In the process of designing the electrical control system, it is particularly important to calculate the electrical load. If the selection is too large, it will lead to waste and it is not easy to protect the equipment. If the selection is too small, the electric energy cannot meet the requirements of the equipment, and the equipment is easy to burn out. Only by fully mastering the basic structure of electrical control of CNC machine tools with vector control, can the design of electrical control system of CNC machine tools be more reasonable, and give full play to its role in practical application [13]. The electrical control system of vector control CNC machine tool is mainly composed of motor, frequency converter and grating ruler. Among the electrical control systems, one of the biggest advantages is the very high control accuracy. The power supply part selects the air switch according to the total power and current of the system. Servo high voltage supplies power to servo power module, which is controlled by AC control loop. The spindle high voltage supplies power to the spindle power supply and controls the spindle motor. Electrical control unit is the core key in CNC machine tools, which involves key parts such as power supply, motor, etc. In addition, it also includes motion controller and other auxiliary parts, which are the key to maintain the operation of CNC machine tools, among which motion controller is the most critical content, which is the premise to ensure the stable operation of the whole electrical control system.

There are two kinds of power modules in CNC machine tools, one is adjustable power module, the other is non-adjustable power module, and the adjustable power module stabilizes the converted direct current into a predetermined variable value according to parameters. The core part of the control system of CNC machine tools is the analysis and use of programs by software. The industrial
computer transmits the correct information to the motion controller by reading the input information, and the motion controller will control the motor module according to the received information, and then control the working area of the CNC machine tool. In the electrical control system, the structural design of the software part is a very critical content, which ensures the effective communication of physical circuits in addition to important modular systems such as industrial computer, power supply module and motor module. High-voltage control is a control system between CNC device and mechanical and hydraulic components of machine tool. Its main function is to receive the spindle speed change, commutation, start or stop, and the selection and replacement of tools output by CNC device. CPU is the core content of vector control. The main performance of vector control is the comprehensive control power of the system, the automatic controller based on the communication ability of the network to each part and the programmable ability of computer technology.

2.2. Composition of electrical control system
In the practice of electrical design, it is necessary to calculate the electrical load. Too much choice will cause huge waste, and it is not easy to realize the protection of equipment. If too little choice is made, it will not meet the demand of equipment for electrical energy, and it is easy to burn out the equipment. Therefore, it is necessary to calculate the electrical load accurately and select the electrical load reasonably. Numerical control machine tool is to use digital control technology to control the movement track of machine tool and the machining process of parts, which is the perfect fusion of digital and machine tool operation. The electrical control unit is an important command center of CNC machine tools, and the main component of the electrical control system is the motion controller. Its main function is to control the movement, logic and process of the main working part, and its normal operation plays an important role in the normal operation of the electrical control system. Vector control has a wide range of versatility and high reliability and anti-interference ability for electrical control equipment. Figure 1 shows the planning results of critical chain method.

![Figure 1 Critical chain method planning results](image)

The working mode of vector control is to scan the system program cyclically. It collects and inputs samples, analyzes the program, and finally outputs a series of control instructions according to the program. Therefore, the main control system of auxiliary electrical system of machine tool is vector control. Input signals include tool changing, tool clamping, air pressure alarm, coordinate axis returning to zero, coordinate axis positive and negative limit signals, spindle speed arrival signals, external operation permission signals, etc. According to the output signal controlled by the program, the program can also be modified to change the output signal or IO allocation according to the control requirements. Output signals include tool rotation, tool change, spindle enable, cooling-on, servo enable, servo high-voltage allow, spindle tightness, etc. Output signals can also be expanded. In the communication system, there is time delay in the data processing and information exchange of power equipment, which seriously interferes with the stable and safe operation of power system. Local data information is the main basis of power control system decision-making. In order to ensure the smooth development of auxiliary decision-making, wide-area signals should also be introduced. However, when in WAMS wide-area control mode, control signals should be sent to different controllers, and there is time delay in data, which interferes with the security and stability of power system operation. When operating the CNC machine tool, press down the over-travel limit switch of a certain axis, and its contact point will be disconnected, which will power off the relay in the control circuit where it is
located, and at the same time send out over-travel alarm information to the system.

3. Stability control of power system
The electrical control system of CNC machine tool based on vector control is a full closed-loop system, which mainly includes frequency converter, motor and grating ruler. The main advantage of the electrical control system is its high control accuracy. Compared with other large-scale mechanical systems, the operation of CNC machine tools is easier, but it does not mean that there will be no problems. In order to further avoid the harm of CNC machine tools to operators during operation. The factor that determines the success or failure of CNC machine tool system is the way of electrical control of CNC machine tool. If you want to make the running speed of machine tool and the precision of processed products reach a higher level, you should pay attention to the advantages and disadvantages of electrical control system. Firstly, the frequency converter is used to change the AC point with a certain frequency into DC, and then the inverter is used to change the DC point into AC with a predetermined frequency. The power supply module mainly includes adjustable and non-adjustable.

The motor used in CNC machine tools is driven by frequency converter, and its gears will be hindered by some lubrication methods when the motor is slowed down. If the gear rotates at low speed, there is no requirement for lubricating oil. Once the rated speed is exceeded, there will be an accident that the lubricating oil will run out. The performance of CNC machine tools can determine the precision and speed of products. The pain curve points out that it is really painful to make a project plan, but it will reduce the pain during and after the project implementation. The pain curve of quality control cycle is shown in Figure 2.

![Pain curve of project control life cycle](image)

Figure 2 Pain curve of project control life cycle

Operators should analyze the conditions of machining parts, understand the functions of the system, and edit the program according to its characteristics. When the operator presses the emergency stop button, the contact of the machine tool itself will be disconnected, and the intermediate relay controlled by the emergency stop circuit of the whole electrical control system will also be disconnected, and the power supply of the mobile device will be cut off. The intermediate relay connected to the vector control input will directly send an emergency stop alarm to the electrical control system, which means that the signal can be used as a reset signal of the system when the emergency stop button is turned on [14]. During the use of the frequency converter, anti-interference measures should be taken for the surrounding electrical appliances. During the use of frequency converter, it will produce a lot of interference electromagnetic waves, which will interfere with some precision instruments around it, so anti-interference measures should be taken for precision instruments around it. In the process of machining, the tool may be worn or broken. Then, in order to ensure the machining quality, it is necessary to test whether the tool is normal. If the tool is worn, the machine tool can change the tool automatically and notify the superior position.

In order to realize the effectiveness of automatic and manual tool change, the spindle is equipped with a special mechanical tool changer and tool magazine. After the manipulator changes the tool, it
automatically measures the depth and position of the tool, which improves the machining quality. When the tool is found to be worn or broken, the detection system of the machine tool will give a prompt, and the automatic tool change and manual tool change can be completed through the system instructions. The system control model is mainly composed of high-dimensional equations, which can calculate the data information in the future. The interaction between automation objects and automation clients is shown in Figure 3.

![Image](image_url)  
**Figure 3** Interaction between automated customers and automated components

In the aspect of system hardware, we should fully combine the running ability of CPU, and install digital signal processor and general-purpose single chip microcomputer. Under normal operating conditions, the over-travel limit switches of the electrical control system are all in a loose state. If the operator accidentally presses down the over-travel limit switches while operating the CNC machine tool, the normally closed contacts will be disconnected, resulting in power failure of the intermediate relay in the control circuit. In terms of communication capability, both external and internal communication belong to the main communication modes of the stability control device, in which internal communication adopts bus mode, which is manifested in two aspects of communication channel number and speed, while system software includes data acquisition, control strategy and fault judgment, etc. Workers should analyze from different dimensions to ensure the authenticity and reliability of data.

4. Conclusions
With the continuous development of industry, the vector control programmable controller is also developing continuously, and is widely used in the automatic control production system of coal mine machinery, and its performance in production control is unmatched by other products. With the continuous development of numerical control technology, the function of vector control for logic processing on numerical control machine tools is becoming more and more perfect, but its function has not been fully exerted. Therefore, it is necessary to design a very suitable and complete electrical control system to cooperate with it, so that the selection of other parts has a very good compatibility. The continuous development of CNC machine tools has promoted the improvement of electrical control system to a certain extent, but the trend of skills applied to CNC technology is few and far between. The electrical control system of CNC machine tools based on vector control is rich in control technology, and in practical application, it has flexible and efficient control characteristics, which can meet the monitoring requirements of CNC machine tools. Through the transformation of mechanical parts and electrical control system of vector control CNC machine tools, the productivity is improved, the automation of CNC machine tools is realized, and certain achievements have been made in the application of CNC machine tools. If you want to complete some complex machining activities, you can change the corresponding control algorithm appropriately, so as to improve the development and design value of the control system, which can not only reduce the cost, but also improve the working quality of CNC machine tools.

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References

[1] He Wei. Analysis of the realization of the electrical control system of CNC machine tools under PLC. Science and Technology Outlook, vol. 27, no. 14, pp. 42-43, 2017.

[2] Li Duoxiang. Discussion on the application of anti-interference measures in the electrical control system of CNC machine tools. Science and Technology Innovation Herald, vol. 15, no. 25, pp. 138-140, 2018.

[3] Fault diagnosis and maintenance analysis of the electrical control system of CNC machine tools. Internal combustion engine and accessories, vol. 000, no. 10, pp. 112-113, 2019.

[4] Sun Zhongqin. Analysis of the fault diagnosis and maintenance of the electrical control system of CNC machine tools. Electronic test, vol. 000, no. 4, pp. 99-100, 2018.

[5] Zhao Detang, Zhang Yi, Wei Haifeng. Permanent magnet synchronous motor multi-sensor combination full closed-loop vector control method. Motor and Control Application, vol. 44, no. 3, pp. 6-10, 2017.

[6] Liu Yaxuan, Wang Qinruo. Research on PMSM AC Speed Regulation System Based on Active Disturbance Rejection Technology. Servo Control, vol. 000, no. 4, pp. 52-54, 2016.

[7] Xue Xiaoming, Chen Zhen. Automatic setting method of PI parameters of permanent magnet synchronous motor control system. Micro special motor, vol. 43, no. 10, pp. 56-59, 2015.

[8] Sha Fengyong, Gao Jun, Li Xuewei, et al. Research on control simulation of multi-inertia servo system for CNC machine tools. Computer simulation, vol. 33, no. 8, pp. 197-200, 2016.

[9] Shao Juan. Research on Intelligent Technology of CNC Machine Tools. Science and Technology Information, vol. 13, no. 2, pp. 95-95, 2015.

[10] Zhang Hongqiang. Research and Application of Robot Controlled CNC Machine Tool Technology. Machine Tool and Hydraulics, vol. 410, no. 8, pp. 151-154, 2016.

[11] Rong Wei. Research on Intelligent Manufacturing and Intelligent CNC Machine Tools. Hubei Agricultural Mechanization, vol. 242, no. 5, pp. 176-176, 2020.

[12] Huang Limei. Talking about the application of machine tool control panel and smart switchboard. CNC machine tool market, no. 4, pp. 42-43, 2020.

[13] Pan Tianci. Research on the electrical control system of CNC machine tools based on PLC. Digital World, vol. 000, no. 2, pp. 311-312, 2018.

[14] Diao Shitai. Analysis of Fault Diagnosis and Maintenance of CNC Machine Tool Electrical Control System. Enterprise Technology Development, vol. 35, no. 7, pp. 91-93, 2016.