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Automatic Machining of Chemical Numerical Control Machine Tool Based on PLC

Xiaoming Wang

Chuzhou Vocational and Technical College, Chuzhou 239000, China
xiaomingwang2812@21cn.com

In order to improve the efficiency and automation level of NC machine tools, this paper puts forward the PLC hole control scheme after analyzing common servo control systems. On the basis of defining motor specifications, the NC electrical control system of machine tools is designed. The output and input modules of the system are defined by the PLC device. The parameters of the input and output signals are clearly defined, and the accuracy of the machine tools is tested and modified. It is found that after the modification, automatic loading and unloading processes are completed, and the processing time is reduced by nearly 30%. The time of changing and moving the tool is reduced by about 28%. At the same time, the accuracy of tool moving is improved. Thus, the automation of NC machine tools based on PLC reduces the down time, the labor input, and achieves the technical targets of production.

1. Introduction

At present, NC machine tools are still not the first choice of the market, which is closely related to the low level of its processing technology, so it is necessary to study the traditional NC machine tool to improve its automation level. Although some enterprises have purchased advanced machine tools from abroad, they are not proficient in the operation technology of NC machine tools and the maintenance of machine tools is not in place, which results in the low efficiency of NC machine tools processing and is not conducive to the development of industry and manufacturing industry in China. Based on this, after analyzing the common servo control system, this paper puts forward the PLC hole control scheme. On the basis of defining the motor specifications, the NC electrical control system of machine tool is designed. Through the PLC device, the system output and input modules are defined, the input and output signals are proofread, the parameters are defined, and the precision of machine tool is tested.

2. Literature review

Before the middle of the twentieth century, people used PCB (Printed Circuit Board) drilling and milling boards mainly by manual and semi-automatic metal punching and drilling machine tools and equipment. Since the early 1960s, many PCB processing equipment manufacturers in industrial developed countries, in order to meet people's requirements, have focused on the existing problems of PCB processing equipment. Finally, the world's first CNC (Computerized Numerical Control) machine tool dedicated to the PCB industry was introduced at the Chicago Machine Tool Expo in 1952 (Flynn et al., 2016). At present, similar products abroad start early, have a long history of development and are relatively advanced in technology, the whole machine is relatively high in grade, and work accuracy and work efficiency are relatively high, but its expensive price, high maintenance costs, difficult parts procurement and other factors make the general PCB manufacturing industry daunting (Han et al., 2017). In the 1960s and 1970s, China began to develop and produce PCB CNC drilling machines. Until the early 1990s, there was no breakthrough in technology. This generation of products belongs to semi-automatic equipment, which requires manual drilling and uses open-loop control system. Moreover, it has low processing accuracy and no auxiliary vacuum cooling equipment, resulting in poor production environment (Martinov and Kozak, 2016). By the mid-1990s, PCB manufacturing industry developed rapidly, and the demand of PCB CNC drilling machine market increased rapidly, which attracted

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the attention of PCB CNC drilling machine manufacturing industry. Research and development of PCB CNC drilling machine began, and a new generation of PCB CNC drilling machine was produced (Feng et al., 2015). Although the performance and accuracy of the new generation of PCB CNC drilling machine have been greatly improved compared with that in the past, it is still unsatisfactory, which results in the scepticism and fear of domestic manufacturing technology at home and abroad for PCB CNC drilling machines (Stock and Seliger, 2016). The discussion on the future development trend of PCB development trend of PCB manufacturing technology at home and abroad is consistent, that is, developing to high density, high precision, fine aperture, fine wire, fine spacing, high reliability, multi-layer, high speed transmission, light weight and thin direction. At the same time, in production, it also develops to improve productivity, reduce costs, reduce pollution, and adapt to the development direction of multi-species and small batch production (Oladapo et al., 2016).

The development level of PCB technology is generally represented by the line width, aperture, thickness/aperture ratio of PCB (Grigoriev and Martinov, 2014). For PCB drilling technology, it develops to small aperture, high precision and speed, and diversified types of holes. Soft PLC (Programmable Logic Controller) has broad application prospects in the field of industrial control. The main foreign producers of PLC regarded soft PLC as the focus of research and development, and launched soft PLC related products (Li et al., 2018). It mainly includes SIEMENS WinAC of Siemens, SoftPLC of SOFTPLC, Concept V2.1 of Schneider Automation, MULTIPROG wt32 of KW Software, ISaGRAF of CJ International, Softlogic TM5 Controller of Rockwell, Codesys 3.0 of 3S (Hu et al., 2016). Among them, SIEMENS WinAC of Siemens in Germany has visual human-machine interface and open development environment, supports ActiveX controls for standardized packages, and integrates many technologies, such as process control, data communication, logical processing and so on. SOFTPLC's SoftPLC has an open hardware structure. The hardware can be chosen freely according to the demand and it can run on a variety of CPUs. It supports a variety of I/O interfaces and high-level language programming. It provides remote monitoring and maintenance functions based on FTP and web server. KW software's MULTIPROG wt32 is based on IEC61131-3 standard and it supports five programming languages. It has both man-machine interface and control program development and has perfect simulation function (Hacksteiner et al., 2017).

To sum up, the above studies mainly focus on the exploration of CNC machine tools. However, there are few studies paying attention to the automation machining CNC machine tools combined with PLC. Therefore, based on the above researches, the automation machining of CNC machine tools is discussed with the help of the PLC.

3. Principles and Methods

The technical basis of numerical control transformation is to analyze and master the machinery of the equipment, the mode of cutting tool, the technical requirements that the processing can meet, the accessories and the technical indicators of processing selenium drum tube after upgrading and transformation. The NC system consists of three parts: calculating the allocation of funds for the drive system, control system and measurement system, and upgrading the three systems according to the annual output of selenium drum tube and the annual growth in the future. NC system is selected according to the overall situation of machine tools and the devices of the input and the output.

An important parameter of ball screw nut is load carrying capacity. Firstly, the average load and the average speed are calculated. Through the experiments under various loading conditions, the operation proportion and the axial load of the ball screw pairs under the rotational speed nl, n2, n3 and n4 are obtained, showing in Table 1 below:

Table 1: Parameters of ball screw under different working conditions

Movement mode	Axial load N	Feed rate	Working time ratio	Feed speed
No cutting	F1=85	V1=3850	Q1=15	N1=450
Light cutting	F2=1850	V2=1100	Q2=33	N2=90
Ordinary cutting	F3=3650	V3=450	Q3=47	N3=30
Heavy cutting	F4=5850	V4=50	Q4=5	N4=5

The slider of the tool holder starts from the origin of the machine and starts cutting after touching the machined parts. At this time, the cutting force exerted by the tool on the spindle is 21000 N. In this paper, the diameter of selenium drum tube processed by automated lathe is not more than 40 mm, which are lighter

parts, so the load moment is relatively small. The 3D mechanical structure design of the shaft is shown in Figure 1.

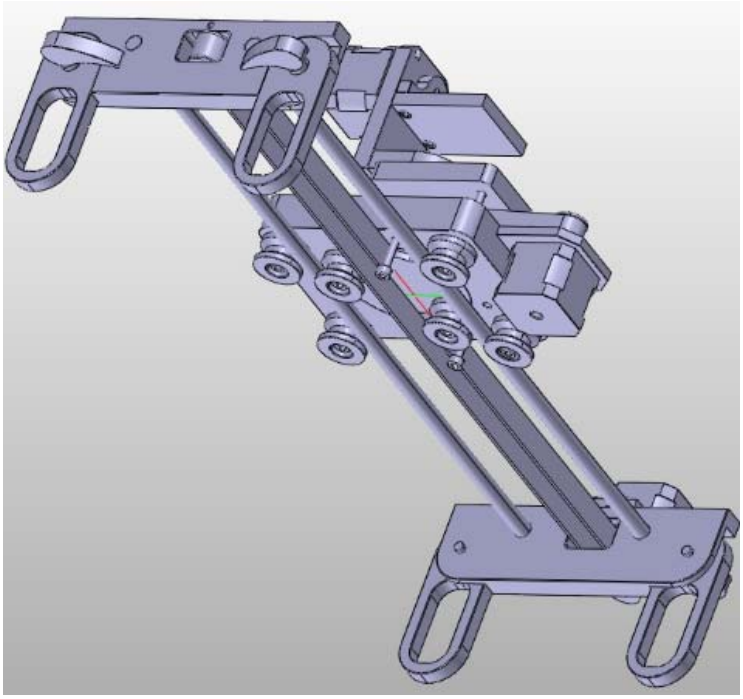

Figure 1: 3D mechanical structure design of the shaft

X-axis mechanical structure design is shown below.

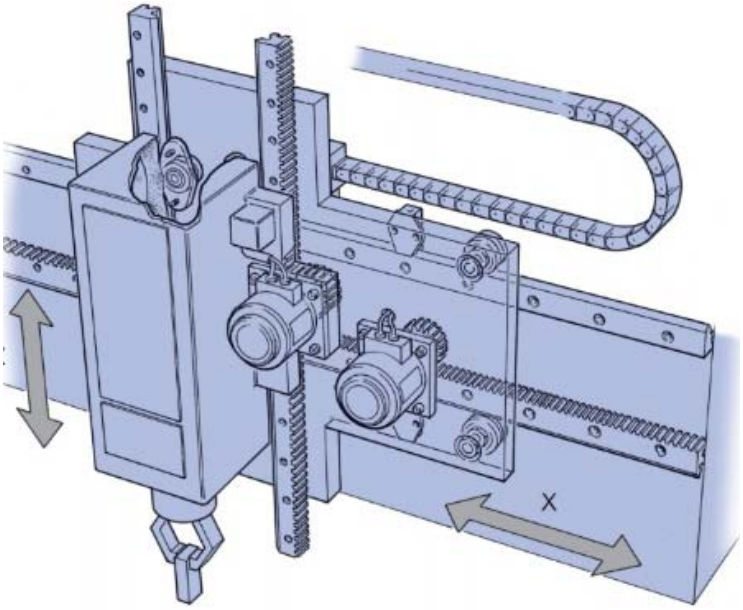

Figure 2: X-axis mechanical structure design

According to the load conditions of two axes, the motor of X and Z axis feeding system of CNC lathe is selected. The two main loads acting on the servo motor shaft are load torque and load inertia. The choice of the motor should meet the following requirements: (1) match the appropriate motor according to the actual check torque. (2) The actual checking torque must be less than the parameters of the motor. The selected motor can not operate overload and must meet the needs of the load. (3) Processing load inertia and motor

rotor inertia should be the same. When choosing motor type, it is necessary to determine the motor according to the rated speed and torque of the motor, according to the processing condition of this transformation, processing performance index of parts, working parameters, and calculating the inertia of the machine load acting on the motor shaft. The moment of inertia of the machine is chosen to select the appropriate motor.
The uniform standard of the rotation of the motor: the precision and stability will be affected by the inertia of the motor, at the same time will affect the real-time response speed of each axis. Machine inertia is proportional to the moment of inertia, the larger the inertia, the worse the performance. Therefore, with stability of the equipment under the premise of invariant in drawing, mechanical structure, inertia should be reduced to the lowest value. The lower the inertia of the equipment, the higher the precision performance in processing; the higher the inertia, the greater the force exerted on the motor when working. It is difficult to control the startup and suspension quickly, so the inertia of the motor and the machine must be consistent. The matching standard of motor inertia should be calculated according to different systems. According to the three data, the mechanical motion parameters and the motor parameters are compared and analyzed. According to the data analysis, although the parameters of YS100-2 motor can meet the index of mechanical motion parameters, the parameters of YS100-2 motor are much higher than those of this lathe, which leads to a waste: the no-load fast starting moment of YS60-1 motor can not reach the parameters of machine tool, and the cutting moment of YS60-2 can not fulfill the requirement, which is thus unavailable, therefore, the YS80-2 type motor matches the machine parameters designed in this transformation. YS80-2 is selected as the X axis feed motor.

Table 2: Machine tool mechanical motion parameters and motor parameters correspondence table

System parameters		Motor parameters			
		YS80-2	YS100-2	YS60-2	YS60-1
No-load fast starting torque	MX=9.199	32	58	26	18
	MZ=20.861	32	58	26	18
Cutting maximum load moment	MX=7.9596	23	34	18	31
	MZ=22.301	23	34	18	31
Rapid feed torque	MX=0.519	32	58	26	18
	MZ=4.371	32	58	26	18

The premise of debugging the software program of PLC is to assemble the hardware of the automatic reformed lathe and debug the parameters of the NC system. The purpose of PLC software debugging is to verify if all functions meet the design logic of the reservation. Firstly, the PLC control program is imported into the programmable controller offline. The preliminary test of the control program is carried out. The input and output circuit diagrams of the PLC control program are compared with the output circuit diagrams of the PLC to check whether the input and output of the PLC control program are correct, and then the erroneous program is modified. Install the electric control cabinet of the lathe according to the compiled electrical control schematic diagram, arrange reasonably, check and install correctly, and then start on-line debugging. Referring to the machine tool processing process, control and test according to the process, adjust the unreasonable program, check whether the PLC control program is consistent with the lathe processing action, test whether the lathe fault alarm processing and electrical self-protection are normal, and finally complete the debugging of the PLC program.

4. Results and Analysis

This mechanical structure, components and NC system of the ordinary vertical lathe have been improved automatically. Especially the improvement of the core structure of machine tool machinery and its assembly, air pressure control, NC system and other important components. The debugging of mechanical structure and PLC control program has been completed. The selenium drum tubes produced in small batches have met the set technical requirements after inspection, and the improvement of lathe automation has met the predetermined targets. The improved lathe loading and unloading structure is shown in Figure 3 below.

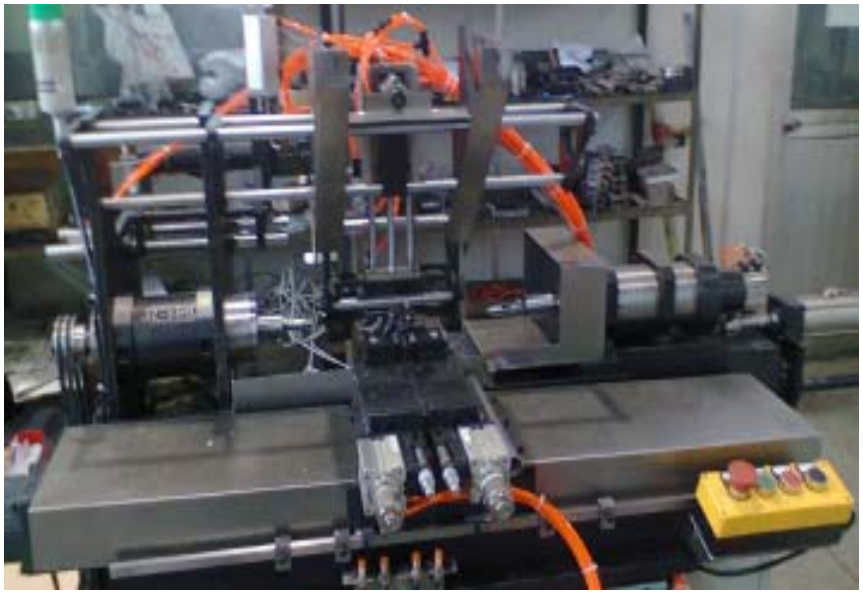

Figure 3: After the transformation of the loading and unloading mechanism

After the NC transformation of the lathe, from the operation status of the lathe and the products processed, the technical indexes and performances have been improved, and the NC vertical lathe has greatly improved the processing accuracy and efficiency; the automation of the NC lathe has been realized in the professional field of selenium drum tube processing, and the function of the automatic lathe pin thread has been realized. And constant line speed section processing function, the quality of the processed selenium drum pipe is also guaranteed safely. In the aspect of automation control of machine tools, the structure of automatic loading and unloading is added to realize the control of single person and multi-machine, which greatly reduces the processing cost. The NC system is equipped with real-time error alarm program. When abnormal problems occur on the lathe, the fault warning information will be displayed on the touch screen, according to the warning and specific error information. By comparing with the operation instructions, the cause of the failure can be identified quickly. Compared with the maintenance before the transformation, the maintenance time is simpler and shorter. The transformation and use of PLC control mode, more integrated the control of the whole system, thus reducing the use of relay components, also reducing many meaningless control lines, thus reducing the failure rate and improving the stability of machine tools. The key technical parameters before and after the improvement of machine tool automation are shown in Table 3 below.

Table 3: Comparison of key technical parameters before and after machine tool automation improvement

		Before the transformation (mm)	After the transformation (mm)
Repeatability	X axis	<0.061	<0.016
	Y axis	<0.046	<0.016
Positioning accuracy	X axis	<0.68	<0.28
	Y axis	<0.42	<0.25
Backlash		0.06	0.015
Fine car outer circle	Roundness	0.01	0.002
	Cylindricity	0.06	0.04
Surface roughness		0.8	0.4

Positioning accuracy and repetitive positioning accuracy: x-axis positioning accuracy, numerical control transformation is up to 0.28 mm, which is originally 0.68 mm, repetitive positioning accuracy, numerical control transformation is up to 0.016 mm, which is originally 0.061 mm. Z-axis positioning accuracy, numerical control transformation is 0.25 mm, originally 0.42 mm, repetitive positioning accuracy is 0.016 mm, originally 0.046 mm. Positioning accuracy and repetitive positioning accuracy are the technical parameters that affect the accuracy of workpiece in machine tool processing. The selection of linear guide with higher precision can

improve the positioning accuracy and repetitive positioning accuracy. In addition, the accuracy grade of ball screw and the pitch compensation function of CNC system are the main factors to improve the positioning accuracy. Before the transformation, the ordinary lathe has no function of automatic feeding and unloading, so it must be operated manually, which wastes a lot of time. After the transformation, the automatic feeding and unloading has been completed, and the processing time has been reduced by nearly 30%. Before the transformation, the machine tool cannot realize the function of automatic tool changing and automatic tool moving. After the numerical control transformation, the machine tool reasonably combines the processing process, realizes automatic tool changing and automatic precise tool moving, reduces the time of tool changing and tool moving by about 28%, and improves the accuracy of tool moving at the same time.

5. Conclusion

Based on the principle of automation control, with the knowledge of the control ability of machine tools and the technological level of traditional lathe, the paper demonstrates the specific technical indicators of processing selenium drum tube. With machine tools as the control core, the machine tool that meets the technical requirements of selenium drum tube processing has been reformed. Finally, after debugging and testing, with friendly and humanized operation interface, the test processing of the machine tool can be controlled intelligently, and can be conveniently operated and maintained.

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