

Fault Diagnosis and Maintenance for CNC Machine

Based on PLC

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Abstract: PLC is an important component of modern CNC digital control system. It is the bridge of CNC and machine tool, which complete logic control based on the input of discrete information. This paper first described the PLC style and function in CNC machine. Then described the method for fault diagnosis according to the alarm code, action sequence, the working principle, the PLC I/O status and PLC ladder, and illustrate the every means.

Keywords: CNC machine tools; PLC; Fault Diagnosis

1 Introduction

The PLC is usually a separate control device, it is an independent control system including CPU, memory, power, I / O interface, and so on. The PLC can be divided into two categories according to the application of CNC machine tools: one is the "inside installation" PLC that is integrated with PLC and NC device by the CNC manufacturers. It subordinates to the CNC devices, and the signal transmission between PLC and CNC devices can perform within the CNC. The signal between the PLC and CNC machine tools transmits through CNC input / output interface circuit. The other is the professional product manufactured by PLC manufacturers, known as the "independent" PLC. The "independent" PLC is independent with CNC devices with a complete hardware and software capabilities. It can complete the control tasks independently.

Information internal processed of CNC can be broadly classified into two groups: one is digital information that controls the movement of coordinate axis, such information mainly complete by the CNC system; the other is discrete information that controls the replacement of control tool, spindle start and stop, speed change, spare parts handling, cutting and stop the opening of the control panel, input and output handling of the panel, that is generally achieved by PLC. PLC in the CNC system is the intermediate links between CNC machine tools and equipment.

The exchange of information in CNC carries out around PLC and transmits among the CNC, PLC and the machine. The exchange of information between PLC and CNC progresses in two directions. The information from

CNC to PLC includes various function code M, S, T, manual / automatic mode, kinds of other information; and the information from PLC to CNC includes response information to M, S, T function and the information of the corresponding reference point for coordinate axis.

Similarly, the exchange of information between PLC and the machine is also divided into two parts. For example, signals include the machine start / stop, the spindle transferred / reverse / stop, mechanical transmission choice, the cooling fluid on / off, rate selection, the coordinates move and support, chuck clamping / release, and also include limit switches of components above all and other protection device, the spindle servo signal and so on.

2 Fault diagnosis and maintenance of PLC in modern CNC

2.1 The fault diagnosis according to the alarm

Modern CNC system is rich in self-diagnosis function, and the fault alarm information can be displayed on the CRT. It is one of the main methods to conduct fault diagnosis of CNC machine tools according to the fault alarm. If the machine has faults, and the alarm information is displayed on the CRT, we must take analysis and diagnosis according to the content of these manual and inspection reports firstly. Some cause of the malfunction can be directly recognized according to the alarm, as long as we understand the content of information, the NC equipment fault can be ruled out. Examples are shown as follows:

Example 1: A system of processing center equipped

with NC SINUMERIK 820 gives an alarm of 7035, and the relative information in the report is the graduator of sub-table does not set down.

Fault analysis: In SINUMERIK810/820 NC system, the alarm of 7 prefix is set by PLC operational information or machine tool plant and it instructs that the side of CNC machine tools system is not in normal state. Approach of dealing with the fault is that put PLC input / output status and copies of the list out according to the fault information and compare. Whether the graduator of sub-table set down or not is detected by the switch SQ25, SQ28 under the table. SQ28 detects that whether the graduator rotates in place, and it is related to PLC inputs I10.6; SQ25 detects that whether the graduator set down in place, and it is related to PLC inputs I10.0. The graduator setting down is completed by the electromagnetic valve YV06 driven by relay KA32 through the output interface Q4.7. Observe from the PLC STATUS, if I10.6 is "1", it shows that the graduator rotates in place, and if I10.0 is "0", it shows that the graduator does not set down. Then observe Q4.7, if it is "0", KA32 relay shall not be electrified, and electromagnetic valve YV06 does not work, so it alarms because the graduator does not set down.

Approach: Move electromagnetic valve YV06 manually, and observe whether the graduator set down or not to distinguish the fault whether in output circuit or in the internal PLC.

2.2 Fault diagnosis according to the principle of control object

PLC procedures of CNC machine tools are designed in accordance with the principle of control object. It is a very effective method to do fault diagnosis through analyzing the principle of control objects and the states of PLC I / Q. Examples are shown as follows:

Example 2: To a CNC lathe system equipped with FANUC 0TC, when tramp on the footswitch, the work pieces can not be chucked.

Failure Analysis and Treatment: In accordance with machine working principle, the first time when the footswitch is tramped, the work pieces should be chucked, and when the footswitch is tramped second time, the work pieces should be released. Let the footswitch connect with PMC input X2.2, and press the button DGNOSPARAM, enter PMC display screen and find that the input X2.2 is zero all the time after the

footswitch is tramped. So we can estimate that there is something wrong with footswitch. Check footswitch and replace it with a new one, then machine works on the rails.

2.3 Fault diagnosis according to the order of action

The automatic exchange actions of devices such as reamers and tool tray on CNC machine are completed in certain order, therefore, observe the actions of mechanical devices, and compare the conditions both in normal and with fault to find out the reasons for the fault. Examples are shown as follows:

Example 3: The control of ATC for a vertical machining centre is shown in Figure 1. When the ATC arm moves to C, there is no lift action.

The initial state of ATC action as follows:① maintain the old tool of spindle to be exchanged; ② the ATC arm is at B; ③ the ATC arm is in the upper position; ④ position the new knife to be exchanged.

The order of ATC as follows: ATC arm moves left (B → A) - ATC arm drops (the knife tool lifts) - ATC arm moves right (A → B) - ATC arm lifts - ATC arm shifts right (B → C, seize the centre knife tool of spindle) - spindle hydraulic cylinder drops (undo the knife) - ATC arm drops (the knife tool lifts from the spindle) - ATC arm rotates 180 ° (two knives exchange location) -ATC arm lifts (install knives)- spindle hydraulic cylinders lifts (seize knife) - the ATC arm moves left (C → B) - the knives rotates (find the location of old knives) - the ATC arm moves left (B → A, return the old knife tool) - the ATC arm moves right (A → B) - the knife rotates(find next knife tool).

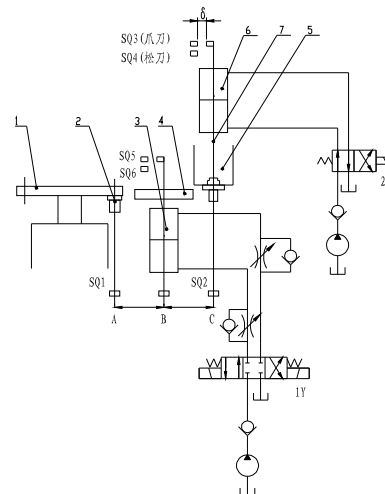


Figure 1 The control diagram of ATC

- 1- the base;2- the knife tool;3- ATC arm fuel tank;4- ATC arm;5- spindle;6- spindle fuel tank;7- pull bar

When the ATC-arm move to position C, no lift action happens, analyze the causes and find there are several possibilities:

(1) There is no signal in SQ2 so that the electromagnetic valve 2Y is without electricity, spindle is still grasping knife, and ATC can not lower.

(2) Release the switch and there is no signal in SQ4 , the ATC arm movements electromagnetic valve 1Y remains unchanged, ATC arm does not fall.

(3) Electromagnetic valve is faulty, ant it does not work even the signal presents.

Gradually inspection, we find that there is no signal sent out by SQ4. Take further examination to SQ4, we find that induction gap is too large to export signal by switch, so a move obstacle occurs.

2.4 Fault diagnosis according to I / O status of the PLC

In NC machine tools, transmission of input / output signal usually achieves through the PLC I / O interface. So, many failures will be reflected in I / O interface of PLC. It is convenient to fault diagnosis according to such characteristics. If there is no hardware failure, we can directly check I / O interfaces of PLC to identify the cause of the fault without seeing ladder graph and circuit diagram, Examples as following:

Example 4: There is a fault in a CNC machine tool that the protective door can not be closed and the machine can not do automatic processing, and the fault doesn't display. The protective door is closed or opened by the gas cylinder, and it is closed by the electromagnetic valve YV2.0 controlled by PLC output Q2.0. Check the status Q2.0, and find it is "1", but electromagnetic valve YV2.0 is not in power. So we can say that the middle relay KA2.0 is damaged because PLC output Q2.0 controls electromagnetic valve YV2.0 by it. Then the fault is excluded after replacement of relay.

There is anther simple and practical method that make a list includes CNC machine tools input / output status and compare the state normal and faulty to diagnose the fault quickly. PLC input / output status are shown in table 1.

Interface	States at present	Normal states	Contents	
input	I0.0	0	1	Urgent stop, break the close touch
	:	:	:	:
	I3.1	1	0	Cooling oil pressure for spindle is too high; the pressure relay SP92 closed
output	:	:	:	:
	I15.7	0	1	The limit switch SQ12 of the graduator disconnected
	Q0.0	1	1	Hydraulic pressure opened and relay KA11 closed
	:	:	:	:
	Q0.4	1	0	The graduator don't break, and break loop YB15 is in power
	:	:	:	:
	Q0.7	1	0	The graduator rotated and relay KA43 closed
:	:	:	:	
Q5.5	1	0	The manipulator move downwards and the electromagnetic valve is in power	
:	:	:	:	
Q11.7	1	0	The knife base rotated and relay KA35 closed	

Table 1 PLC input / output status

2.5 Fault diagnosis through PLC ladder graph

It is a basic method to analyze and diagnose fault of NC machine tools according to the PLC ladder graph to solve the external fault. To do machine fault diagnosis in this way, we should understand the principle of machine tools, action sequence and interlocking relationships at first, and then use the self-diagnosis function of CNC system or view the associated input / output and signs in the state according to PLC ladder graph to thus confirm the reasons for the faults. Some times, there are some PLC faults but the input / output and signs are in normal state, then we should track PLC and observe the input / output and signs instantly, and diagnose at last according to the principles of action of PLC. Examples as follows:

Example 5: A two-spindle and two-position CNC machine tool equipped with the system SINUMERIK 810 is shown in Figure 2.

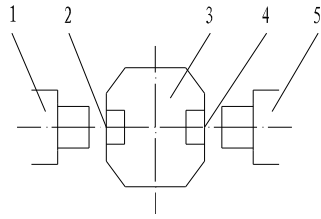


Figure 2 A two-spindle and two-position CNC machine tool

Fault Introductions: The machine running in AUTOMATIC, after the work piece at position 1 was finished, and the spindle at position 2 was not felled back in place and rotary table was about to spin, the spindle at position 2 stopped and automatic cycle was disrupted with a warning. The content of the warning said that speed of the spindle at position 2 is not normal. We can not find problems though inspection on the main drive system and the speed of two spindles is detected by two sensors B1 and B2. Next, we observe the status ladder graph using the programmer. F112.0 is the starting flag for the spindle at position 1; F111.7 is the starting condition for the spindle at position 2; Q32.0 is the starting output for the spindle at position 2; I21.1 is the clamping detection input for the spindle tool at position 2; F115. 1 2 is the clamping flag for the spindle tool at position 2.

Observe the status of ladder graph (as shown in Figure 3) in the programmer, and we can find that if the status of F112.0 and Q32.0 all are "0", there will be some faults. The spindle stopped and F112.0 was "0" caused by B1, B2 witch detected the speed of spindle abnormally. Observe the dynamic changes of Q32.0 and find that F112.0 and F111.7 were closed when there were no faults. When there was fault, F111.7 disconnected instantly, followed closed immediately, the state of Q32.0 changed into "0" with the disconnection of F111.7, and at the same time, the state of F112.0 became "0", so as to maintain the status of Q32.0 "0", and the spindle stopped. B1, B2 detected the speed abnormally due to instant disconnection of Q32.0 with F111.7 and F112.0 became "0" followed. The starting conditions F111.7 of spindle were restricted by many factors, and we observed the ladder graph and found that F111.7 changes were caused by F111.6. We checked the ladder graph PB8.3 sequentially and found the signs F115.1 for knife tools change "0" instantly, so F111.6 changed. Continue to track the ladder graph PB13.7, observed that I21.1 instantly disconnected and F115.1 changed "0" instantly

when there is fault, the spindle stopped finally. I21.1 is the signal for detecting the hydraulic pressure of blocking tools, and if it disconnected, the hydraulic pressure was not tight enough. Duo to the analysis above, we can diagnose that the fundamental reason for the fault was the fluctuations of the hydraulic pressure. Adjusted the abnormal hydraulic so that the fault was disappeared.

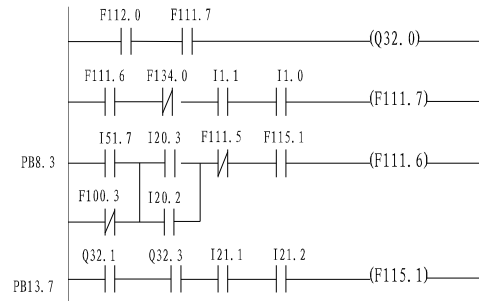


Figure 3 The status of ladder graph observed in the programmer outside

3 Conclusions

In order to rule out the fault related to PLC timely, we need to understand the installation positions of detection switches for the various components of the NC machine tools, such as the knives base of the processing centre, the mechanical hand and rotary table, the rotating turret and tail planes, the limit switches, the touch switches and pressure switches, etc., identify detection switch as signs of PLC input signal. Also we need to understand the action sequence of the implementation, such as hydraulic cylinders, the electromagnetic valve cylinder, and identify the corresponding PLC output signals signs and understand the conditions signs, such as start, stop, limit, clamping signs and releasing signals, and so on. With the necessary diagnostic function, if necessary, use the programmer to track dynamic changes of the ladder graph to understand the reasons for the failure, and make the diagnosis according to the principle of machine tools. The fault diagnosis method is not a single because of the different fault forms of PLC control module. Sometimes, we should use several ways to analyze the fault synthetically, and narrow the scope of failure gradually to get the correct diagnosis quickly, and rule out the fault finally.

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This paper attaches to “Advanced equipment fault diagnosis, maintenance and repair techniques”

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