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Research on systemic design of electronical control for numerical control machine tool

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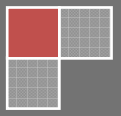
ABSTRACT

The rapid development of numerical control (NC) machine tool has been a necessary guarantee to enhance production efficiency, while for the design of electronic control system, which undoubtedly has a positive effect on NC machine tool. Further study on design of electronical control system for NC machine tool has been a key to increase productivity. Bring together relative study and discussion on the design process of each branch system in electronical control system with related case study, this thesis possesses a solid practical basis in the process of research and discussion. Beginning with comprehensiveness of electronical control system, the paper makes an omni-bearing discussion on relative design of different systems, in which, the intelligence and scientificity of numerical control machine tool are gradually enhanced to maintain the design thought in high degree of clarity and make design concept have strong rationality for providing solid theoretical and practical basis for further development.

KEYWORDS

Numerical control machine tool; Electronical control; Systemic design; Case study.



INTRODUCTION

Numerical control machine tool has played a decisive role in industrial production, while it is also the inevitable product of the development of science and technology. In order to embody its scientificity to the largest degree, the key is to maintain the systemic research and development as well as the design thought in high degree of clarity. Combining with systemic design of electronical control for spindle motor, electronical control design for feed shaft, design of PLC module, systemic switch and urgent stop system, this thesis conducts corresponding design from the four respects to gradually refine the research focus for providing solid theoretic foundation for the overall development and construction of electronical control system in NC machine tools. On the basis, case studying on the design process to make the research and discussion more persuasive.

SYSTEMIC DESIGN OF ELECTRONICAL CONTROL FOR SPINDLE MOTOR

In the process of building control system for spindle motor, there are several requirement aspects: firstly, the revolving speed of spindle motor itself should remain stable; secondly, in terms of addition and subtraction of the speed, reflection should be more flexible; thirdly, when spindle motor is revolving in low speed, its torque force should maintain bigger while its overload capacity should be relatively strong. For a machine tool, it is an important power transmission route of machine tool in operation. In the process of research on the thesis, the specific type is lokson650 vertical milling machine[1]. Therefore, during the operation, the corresponding cutting of the workpiece depends on the spindle while the spindle driver selects YASKAWA inverter as the core of vector control mode, equipped with brightening instrument to provide positive information feedback for regular work of spindle velometer.

Description for principle of electronical control in spindle motor and work process

The design of spindle electronical control is shown as Figure 1. The applied range of this type of machine tool is reflected in effective processing of metal products and at the same time, it plays a positive role in production of small-sized moulds. In the operation of machine tool, the specific parameters of spindle motor should be set effectively: rated voltage is 380V; rated power is 3.7KW; rated current is 13A; rated frequency is 50HZ; revolution is guaranteed to achieve 1500 R/min and the highest revolution does not exceed 8000 R/min. In the design process of spindle driver, frequency converter should be effectively used in the driver to make rated power rise to 5.5KW and rated current remain unchanged while voltage is still kept at 380V. The group of parameters can meet full needs of metal products and meanwhile, the manufacturing of small-sized moulds can meet the corresponding requirements. According to above parameters, we should choose the type Chen Chang YD90L-4/2 as spindle motor.

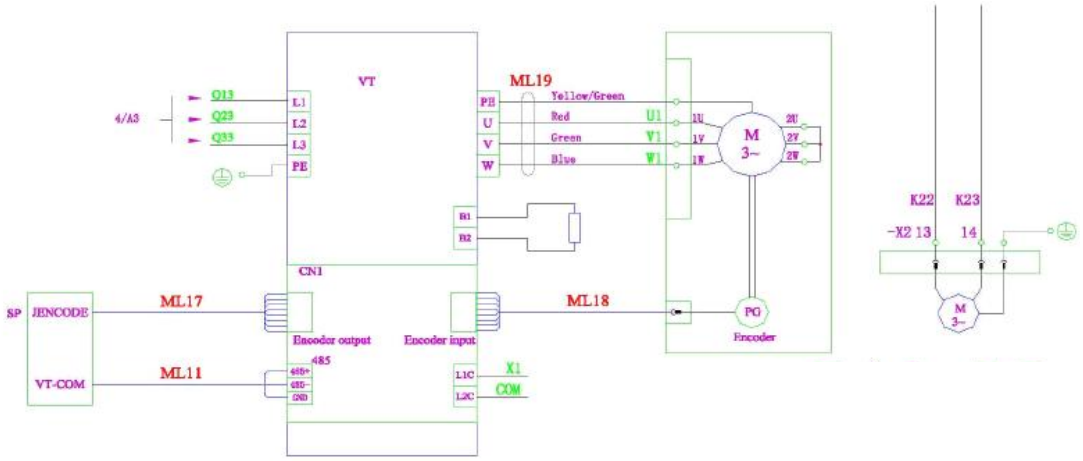


Figure 1 : Design of spindle electronical control

Systemic design of electronical control for spindle motor

After the motor operating with heavy load for a long time, the motor will dissipate excess heat, which will result in increased heat and at the same time, the load will be exceeded greatly. During constructing process of spindle motor control, motor's temperature should be set at 110℃ as overheating standard, which should be taken as concrete threshold value of overheated temperature. During the process, after the scheduled range is surpassed, it will send massage to control system every two minutes and then, the system will deal with it effectively according to the information, which is mainly embodied in the start of alarm device[2].

However, in other unusual situations, we can hypothesis that the internal part of spindle motor produces slight change, such as speed adaptation is interfered or the power is abnormal etc.. The system will send the signal to relevant control system through variable frequency detector, and at this moment, the alarm device will be started. But if we assume that power is suddenly cut off or there is something wrong with external voltage stability, the problems caused by the external factors will be handled by internal system of motor itself. If power is cut off suddenly, internal components of motor will store the important data effectively to keep the data available before the power is restored, which will provide support for normal operation of the motor; if short-circuit is formed suddenly, internal current of the motor will continually increased and at this moment, function of leakage switch will work. During the process of designing leakage switch, all current intensity which reaches 30A will switch off automatically. Only in this way, can workers as well as some important components of machine motor escape from damage.

The setting of spindle parameters

The set value of spindle parameters is shown as TABLE 1.

TABLE 1 : Set value of spindle parameters

Set Value	Notes
1	Rotating direction set of S axis in servo motor: Switch through 0 or 1. When the direction of motor driven by X axis servo motor is opposite to predetermined coordinate direction of X axis machine tool, it switches through 0 or 1.
1	Reading direction set of S spindle encoder: Switch through 0 or 1. When reading direction of S axis encoder is opposite to the direction of S axis motor, it switches through 0 or 1.
0	Type of spindle servo control: 0: VT bus 1: M 2 bus 2: sercos 2 bus
4096/1	Pulses set of S axis encoder: set as 4096 generally (after the number of spindle motor is 1024,4 times of frequency, pulse is 4096) if spindle has no encoder, set as 1
0	Revolution set of spindle [0~1000000](R/min) It is used for setting revolution of spindle when system does not execute code program.
0	Location angle of spindle [0~359999](0.001 °) Location angle of spindle is set as negative direction when spindle is locating.
10	Revolution location of spindle (R/min) Revolution is set when spindle is locating: the faster the speed is, the faster the location is but is not too high.
300	Revolution equivalent of spindle for every 10 HZ (r/min). For example, if the rated frequency of spindle motor is 50 HZ and corresponding rated revolution without load is 1500r/min, equivalent should be set as (1500/50) * 10= 300

Self stabilization of debugging motor parameters of spindle frequency converter (VT converter)

(1) Initialized driver parameter P0.01= 5: restore factory parameter;

(2) Preset frequency set of converter: P0.05: frequency of self stabilization when rotating;

(3) Self stabilization parameter set of converter in accordance with nameplate parameter of motor (different type of motor has different nameplate parameters): P9.01: electrode number P9.02: rated revolution P9.03: rated power P9.04: rated current;

(4) Ways of setting self stabilization parameter: pressing RUN, it will start working: P9.15=1: stop way of self stabilization P9.15=2: rotate way of self stabilization;

(5) Observing whether converter gives an alarm because of overloading: if it is, switch parameter Pd.22; Pd.22: rotating direction of encoder. When feedback direction of code is different from rotating direction of motor, employs 0 or 1 to switch parameter;

(6) After self stabilization parameter, set converter parameter according to parameters;

(7) Set method of system control and operate the motor;

(8) Debugging spindle location angle.

DESIGN OF ELECTRONICAL CONTROL FOR FEED SHAFT

This type of NC machine is half linear rail machine, that is to say, X axis and Y axis adapt linear rail while Z axis uses hard rail. Because of the small contact surface of feed shaft employing linear rail and basic machine, small friction, resistance as well as the lighter capacity, the machine is generally used for cutting with light load, processing metal parts and auto parts etc.; while because of coarse side of feed shaft which employs hard rail, high friction and strong load capacity, it can be used for cutting with heavy load, processing mould products. The usage of the machine—LOKSON650, employing

half linear rail, is a kind of product between above types of machine, which is mainly used for processing metals, auto parts and small mould etc.. Therefore, its requirements for cutting are divided into: requirement of feed shaft and spindle. The requirement of spindle has been given above, thus, here will not repeat it. The following will mainly discuss the requirement of feed shaft:

[1] Accuracy requirement: ① repeat location accuracy is 0.005mm; ② location accuracy is 0.001mm;

[2] Fast requirement: acceleration and deceleration are good, three-axis simultaneous motion is smooth, following performance is good, average processing speed per second is 20cm/min and the fastest speed can achieve 1m/min;

[3] Requirement of stabilization: small vibration and strong ability of anti-interfere etc..

During the course of designing for control system of X, Y and Z axis feed shaft, it is the difficult core part of the systemic design. Hence, full study and exploration on selecting control system of X, Y and Z axis feed shaft as well as servo driver are proceeded. Finally, ANCHUAN servo motor and SGMD-20ADA servo motor are chosen[3].

As the two servo axis- X and Y are exactly the same, therefore, aspect of selecting servo motor should be maintained high consistency: rated power is 1.8KW; rated current is 3A; rated torque force is 500N/m; rated voltage is three-phase 220V; rated revolution is 1500RPM and the highest revolution is 3000RPM. Corresponding parameters of servo motor driver are: rated voltage is three-phase 220V; rated power is 2KW; rated current is 2A and rated frequency is 50HZ.

While because Z axis is rigid guide rail with larger resistance itself, its capacity of loading is stronger. It indicates that Z axis is different from the other two servo motors: its rated power is 2.9KW; rated current is 5A; rated torque force is 1000N/m; rated revolution is 1500RPM and the highest revolution is 3000RPM with function of braking. Its corresponding driver is different from X and Y axis servo motors too: the type is SGMD-30ADA; rated power is 3KW; rated current is 5A; rated voltage is three-phase 220V and rated frequency is 50HZ.

Description of principle and working process of electronical control for feed shaft

During the process of designing electronical control for feed shaft, the designing principle of X, Y and Z axis are highly consistent. For this, we can take the construction of electronical control for X axis servo as an example to accordingly discuss its working principle and process. The design of X axis servo driver is shown as Figure 2.

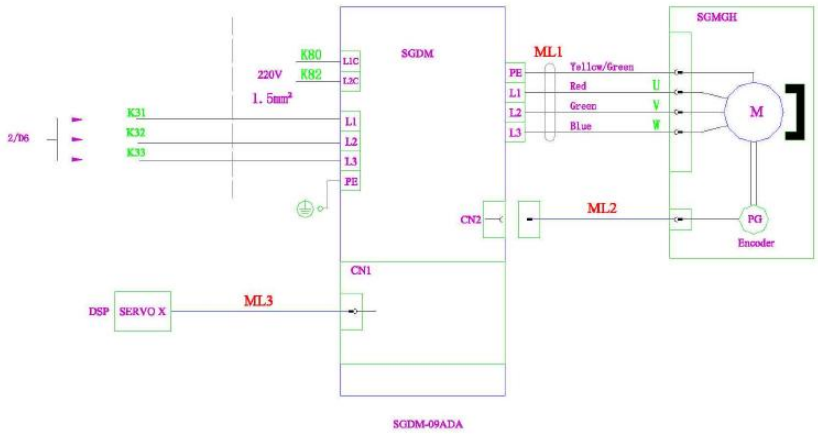


Figure 2 : Design of X axis servo driver

For each driver, it has its corresponding motor. After receiving signal from spindle potential energy in spindle program, the driver can start to work, which indicates that there is no problem in the driver and at the same time, the driver will transmit a responding signal to spindle system. In the meantime, the driver should obtain corresponding positive and negative potential signals from operation panel of the machine tool. After receiving the two signals, it is proved that the driver is ready for starting. Until spindle control system emits relevant command, the motor can operate normally. However, if there are any unexpected circumstances during the process of effective operation, spindle control system will issue urgent stop command. Only in this period, can motor stop operating. The voltage of industrial voltage is three-phase 380V. Through the main switch and contactor, the industrial voltage will be reduced to 220V and will be accessed to servo motor with X, Y and Z axis directly through capacitor. Connecting servo controller with terminal between electrodes, the system will supply sustainable and effective power for the motor. During the course, driver also plays a basic role in effectively controlling and regulating speed of the motor, while the motor takes optical code device as information transmission medium to feedback effective information about specific situation of motor's operation and information acceptor is motor driver[4].

Press start button SB1 and the relay will close electricity. Continuously press the second start button SB2 and the relay KA2, KA3 and KA4 will close electricity to be able to obtain potential signal of spindle. The motor will start relevant

work in accordance with related command for influenced by consistent signal of spindle control system. The Output of Intermediate Relay is shown as Figure 3.

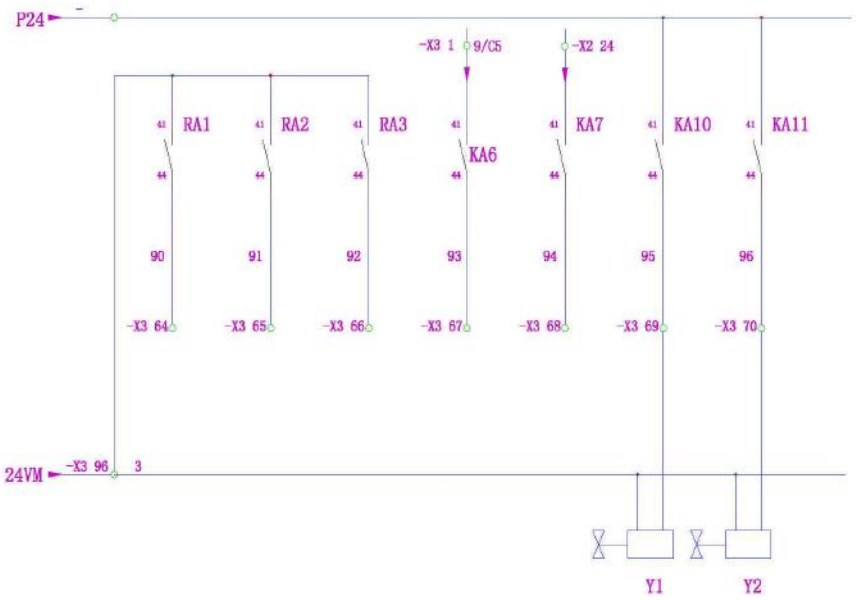


Figure 3 : Output of intermediate relay

Handling limit control of the feed shaft and abnormal situation

From SQ1 to SQ8, they are lead limit switches which play role in positive and negative of three axis respectively. No matter which switch is pressed, the signal will be cancelled automatically and the movement will be stopped. While if press the position switch SQ1, the potential energy on X axis will lose effect and then lead to the servo motor on X axis can't move reversely; if start its function of limit protection, the servo motor on X axis can move forward until the workbench leaves from SQ1. Among this, spindle control system set relevantly the parameters to protect concretely the soft position.

In some abnormal circumstances, firstly, effective judgment of the causes should be done. However, in feed shaft module, the abnormal situations usually happen in motor's control system or the unload ontology appears abnormal factors. Usually, the abnormal situations in unload ontology only include position anomaly, prop anomaly and motor with abnormal circumstance[5].Because these circumstances will happen at any time, the operators should pay more attention to these. The happening of these situations is not because some design issues appeared in practical process of the system, but because there is something wrong with the spindle NC system to make the information sent mistakenly. Another possibility is that external factors cause the abnormal situations in spindle NC system, such as power cut suddenly and short circuit etc. Therefore, at the beginning of designing, these factors should be fully taken into consideration to effectively avoid these circumstances. For example, in situation of short circuit, current in internal motor will be increased constantly while the installed leakage switch can protect it from leaking electricity to cut off power automatically so that the machine can get better protection.

DESIGN OF PLC

Usually, the programmable logic controller (PLC) will begin to work automatically after the equipment is turned on, whose specific working principle is the work mode of scanning cyclically. The working process can be divided into three phases: the first phase is input of sample, the second is execution of the program and the last is output of the program and auto refresh. This kind of controller is fully used in NC machine, whose function is to effectively control auxiliary equipment, including cooling system and lubrication system etc..

Overall external wiring design of PLC

In the course of designing the system, the control of lubrication system consists of two inputs and two alarm outputs while the cooling system is consistent with lubrication system, including two inputs and two alarm outputs too. In the process of designing automatic tool setting, the system is made up of six inputs and six outputs while in the course of designing lighting system, it is composed of one input and four outputs. However, the tool changing system consists of five inputs and five outputs. In choosing PLC, Huichuan 22415uHCMR automatic programmable logic controller is selected for carefully taking allowance into consideration. This kind of controller has twenty four inputs and fifteen outputs, whose scanning frequency can reach 1000HZ and requirement for designing the system can be met. From TABLE 2, more details can be got from the distribution of I0 point outside PLC.

TABLE 2 : Distribution of IO Point Outside PLC

Input Point X0	Signal of Left Tool Setting on X axis	Out Point Y0	Potential Energy of Left Tool Setting on X axis
Input Point X1	Signal of Right Tool Setting on X axis	Out Point Y1	Potential Energy of Right Tool Setting on X axis
Input Point X2	Signal of Front Tool Setting on Y axis	Out Point Y2	Potential Energy of Front Tool Setting on Y axis
Input Point X3	Signal of Behind Tool Setting on Y axis	Out Point Y3	Potential Energy of Behind Tool Setting on Y axis
Input Point X4	Signal of Upper Tool Setting on Z axis	Out Point Y4	Potential Energy of Upper Tool Setting on Z axis
Input Point X5	Signal of Lower Tool Setting on Y axis	Out Point Y5	Potential Energy of Under Tool Setting on Z axis
Input Point X6	Reservation	Out Point Y6	Reservation
Input Point X7	Reservation	Out Point Y7	Reservation
Input Point X8	Signal of Lubricating Oil Shortage	Out Point Y8	Lubricating Oil Shortage Alarm
Input Point X9	Signal of Coolant Shortage	Out Point Y9	Coolant Shortage Alarm
Input Point X10	Reservation	Out Point Y10	Reservation
Input Point X11	Signal of Excessive Lubricants	Out Point Y11	Excessive Lubricants Alarm
Input Point X12	Signal of Excessive Coolant	Out Point Y12	Excessive Coolant Alarm
Input Point X13	Reservation	Out Point Y13	Reservation
Input Point X14	Hand Tool Unclamp	Out Point Y14	Tool Unclamp
Input Point X15	Automatic Tool Unclamp	Out Point Y15	Tool Clamp
Input Point X16	Magazine Clamp	Out Point Y16	Cutter Forward
Input Point X17	Cutter Forward	Out Point Y17	Cutter Reverse
Input Point X18	Cutter Reverse	Out Point Y18	Cutter Onward
Input Point X19	Cutter Onward	Out Point Y19	Potential Energy of Tool Arm
Input Point X20	Magazine Operation Illegally	Out Point Y20	Magazine Operation Illegally Alarm
Input Point X21	Reservation	Out Point Y20	Reservation
Input Point X22	Start Button	Out Point Y20	Start Lamp—Lighting
Input Point X23	Urgent Stop Button	Out Point Y20	Reservation
Input Point X24	Reservation	Out Point Y20	Reservation
Input Point X25	PLC Power—Live Wire	Out Point Y20	Signal Light—Green
Input Point X26	PLC Power—Null Line	Out Point Y20	Signal Light—Yellow
Input Point X27	Reservation	Out Point Y20	Signal Light—Red

Design of lubrication and cooling control system

During the process of establishing and studying the system, because the principles of lubrication control system and cooling control system are generally the same, they will be not discussed separately but discussed together through effective

arrangement. The maintenance of machine toll is necessary to improve accuracy when machine tool is operating while the errors produced by machine tool can be regulated at the first time through effective debugging. Combination of the two aspects can continuously increase life expectancy of the machine tool and at the same time, can provide guarantee for constantly enhancing accuracy in the process of operation. However, for lubrication and cooling systems, there are two problems in basic electronical control: on the one hand, the process of lubricating and cooling is generally in operation when machine tool is working and on the other hand, because of relative fixed time for lubrication and cooling supply as well as single circulatory system, it is possible to lead to waste of resources. For the basic condition of the two aspects, effectively innovating cooling and lubrication control system and monitoring the process in real-time can make each part get corresponding supply. Through cycling, the change of dynamic replenishment can be formed, the parts that lack of supply can be supplemented at the first time and then the resources can be effectively saved[6].

Design of lighting and signal lamp system

The lighting system should start by itself after machine tool is opened, however, the lighting system set in control cabinet should start too as soon as contacting control cabinet and should close the moment control cabinet is closed. The signal light only open yellow light at the moment of opening machine tool while open red light under the condition of meeting urgent stop and receiving alarm. During the system is operated normally, it will display green.

SYSTEMIC SWITCH AND URGENT STOP SYSTEM

From Figure 4, it can be observed that SB0 is main switch of the control system. When the main switch is pressed, intermediate relay gets electricity to make the whole system connect with power and supply low voltage for processor, demanded platform and control panel via power in switch. At this time, the whole system begins to be in motion normally. However, as urgent stop button, when SB1 is pressed, the relays such as RA16, RA11 and RA12 will lose power one after another and then, the power supply between spindle and feed shaft will be cut off. The result is that the parts between them will stop spinning[7]. After removing abnormal faults, restoring urgent stop button to original position, the parts between spindle and feed shaft can working normally. However, the intermediate relay will close electricity one by one, at this time, red signal light will be on accompanied by corresponding alarm to warn operator to correct their mistakes.

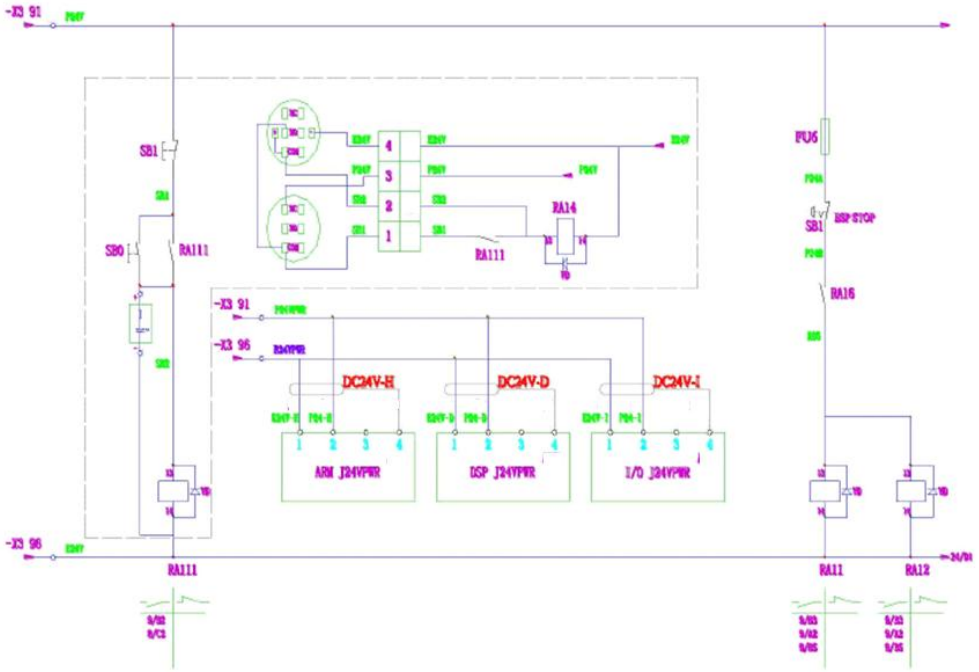


Figure 4 : Systemic switch and urgent stop circuit

CONCLUSIONS

Above is the relevant research and exploration for systemic design of electronical control of numerical control machine tool. In the combination with the existing design to improve its characteristics accordingly so that the intelligent characteristics of NC machine tool can be fully displayed. By case studying the design process of different systems, research and discussion of this thesis become more pertinent, which has positive effect on changing design concept of electronical control system in NC machine tool.

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