Study on the Control System of the Lathing and Welding Compound Machine Tool

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Abstract. Most conventional Computer Numerical Control (CNC) systems are single process method, so one working procedure need several steps to complete. The Combined machining NC system can solve this problem. In this paper, the hardware construction of the lathing and welding compound machine tool control system is studied and the software structure is also discussed.

1 Introduction

Combined machining now is becoming one of future directions for the machine tools in the world. More and more complicated parts begin to be processed with the compound machine tool. Compound machine tool can improve efficiency of production parts with low volume and rich varieties considerably, suitable to produce Aeronautics & Astronautics parts. In order to solve the problem of large-scale structures' welding, a fabrication method, which performing the turning and welding on the same special equipment, is studied in this project. It is improved that it can simplify the manufacture process, improve welding efficiency, guarantee the welding quality and improve the lifetime. The thin wall pipe lathing and welding compound machine tool is composed of an automation lathing system and an automation welding system. With twins-milling head, the compound machine tool can finish the lathing and welding process of the thin wall pipe and flange with no declamp operation.

2 Control System Design

With the three degree-of-freedom Manipulators and a special clamp, the compound machine tool can realize the thin wall pipe lathing and welding on the same tool without a second clamping. The motion model of the compound machine tool is shown in figure 1.

The compound NC machine tool consists of three parts, a CH2010/S ONC system made by BUAA as the control system, a corresponding AC motor and a photoelectric encoder as the executive component and the reactive component of servo system. NC device of the control system compiles of the program and sends order to the servo system, and then the servo system controls the motor's movement. In the whole movement process, the photoelectric encoder mounted on the corresponding AC motor detects the displacement and velocity of the compound machine tool, and this information is feed back to controller by the feedback system. After comparing the

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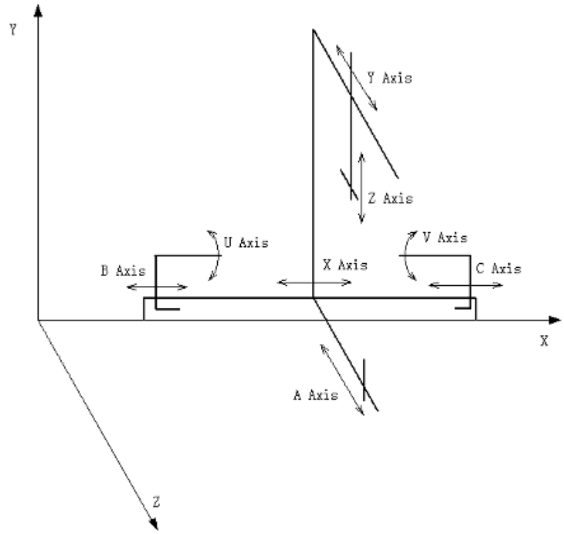

Fig. 1. Motion model of the compound machine tool

actual displacement and velocity with the target value and other information, the controller sends new orders to the corresponding AC motor to produce corresponding movement which can rectify the movement of the compound machine tool[1]. It is a real-time detection, feedback and closed loop control system. The whole control structure of the lathing and welding compound NC machine tool is shown in figure 2.

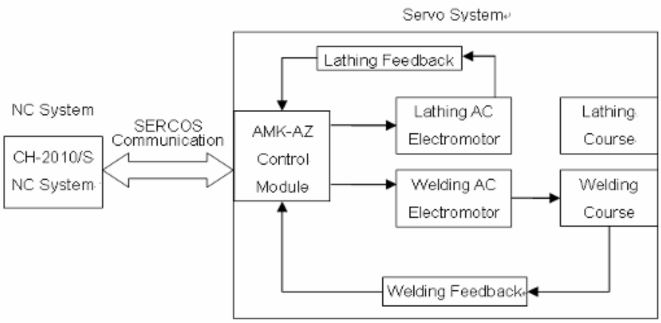

Fig. 2. The whole control structure of the machine tool

3 Hardware Constructions

The hardware part is composed of a CH-2010/S control system, an AMK AC servo module and 8 induction AC servo motors. The CH-2010/S control system is a open

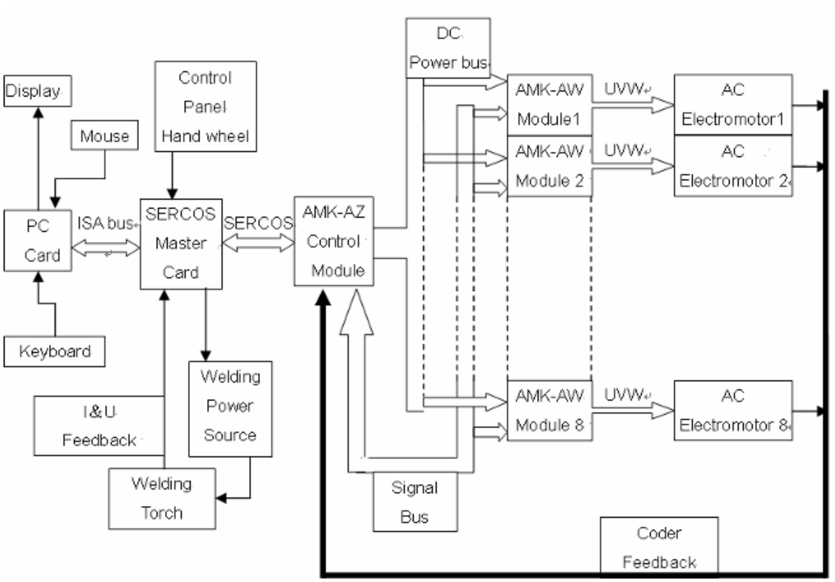

Fig. 3. Hardware construction of control system

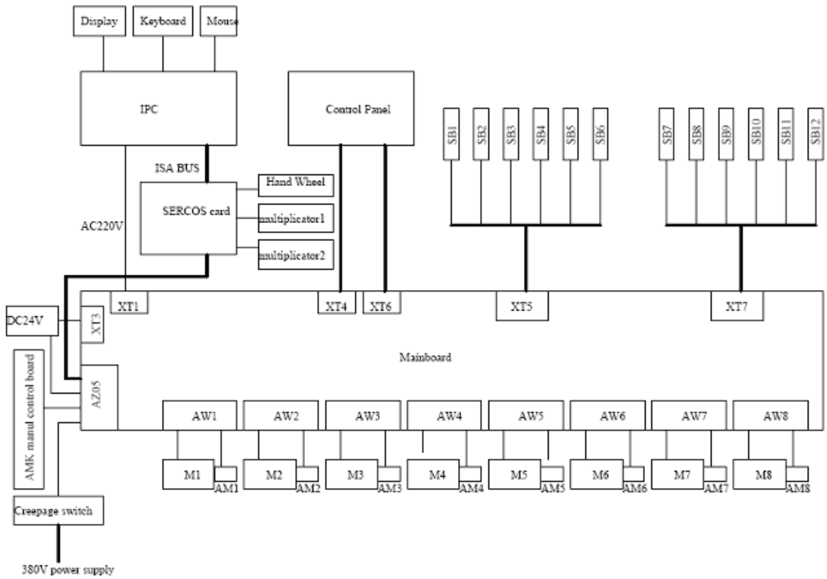

Fig. 4. The hardware hookup of the control system

controller system which is based on the PC computer and field bus SERCOS technology, and its hardware construction contains two cards, one is the PC main-board card, another is the SERCOS-Master card. NC-PLC kernel operates the

SERCOS-Master interface card with SERCOS-Master driver program and the SERCOS-Master card connects with the AMK AC servo module. The AMK AC servo module is used as the control module. The AMK-AZ sends signals to AMK-AW when any numeric control command receives from SERCOS. And then the AMK-AW exports the signals to three phase induction AC servo motors. The hardware construction of the control system is shown in figure 3.

The SERCOS-Master card has the machine tool operation buttons, multiple switch and handwheel port which are available for all kinds of NC machine tools. The CH-2010/S controls the machine tool control module with the SERCOS-Master card, which is composed of 1~50 SERCOS feed stages and 40~320 PLC-IO ports. The hardware hookup of the control system is shown in Figure 4. In this figure, the AW# means AMK servo module, M# means the number of motor, AM# means the coder relative to motor, and SB# indicates located restrictive switch of the machine tool.

4 Software Constructions

All kinds of resources provided by the WINDOWS operating system can be used conveniently in the CH-2010/S. It offers the software application environment and a group of normal system performance functions to users, such as: [2][3]

1. The Manipulative Performance, including the manipulative menu, coordinate display, operating states display and graphical display etc.
2. Data Management System, including system parameters, tools data, NC programs, files and table edit.
3. System Soft Interface, sending the NC variable, NC data and PLC variable to the NC-PLC kernel and reading them from it.

With the NC variable, NC data and PLC variable, the commands and data are transferred between the CNC system software and application software. NC variable is used for sending control orders such as the selection of work type, cycle starting, feeding keeping and reset operation etc from application software to NC kernel, or

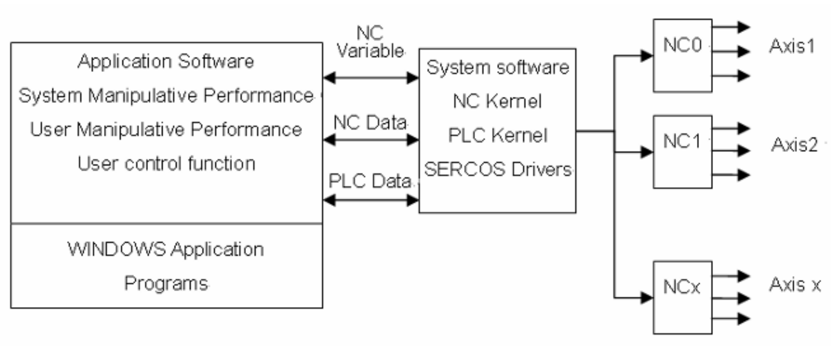

Fig. 5. CH2010/S NC software environment

reading the machine tool coordinate and the NC kernel work states from the NC kernel. The NC data include the NC program, tool data and machine tool parameters etc. Using the PLC variable, the orders can be sent to the PLC kernel from application software straightway and the information of PLC kernel can be read. The PLC kernel offers plenty blending function for invoking. The NC software environment of the CH2010/S is shown in figure 5.

Based on object-oriented technology, in the open CNC software, the control system is divided into many functional modules to accomplish different functions. The C/S module is used for transferring the information between modules and control system kernel or different modules[4][6]. The module offering service function is the server module and the module asking for the function service is client module.

For the scalability, maintainability and reconfiguration of CNC system software, the software is designed with modular method. Based on the control system function, different modules are designed for multi-task ability of control system. The logic diagram control program is shown in figure 6.

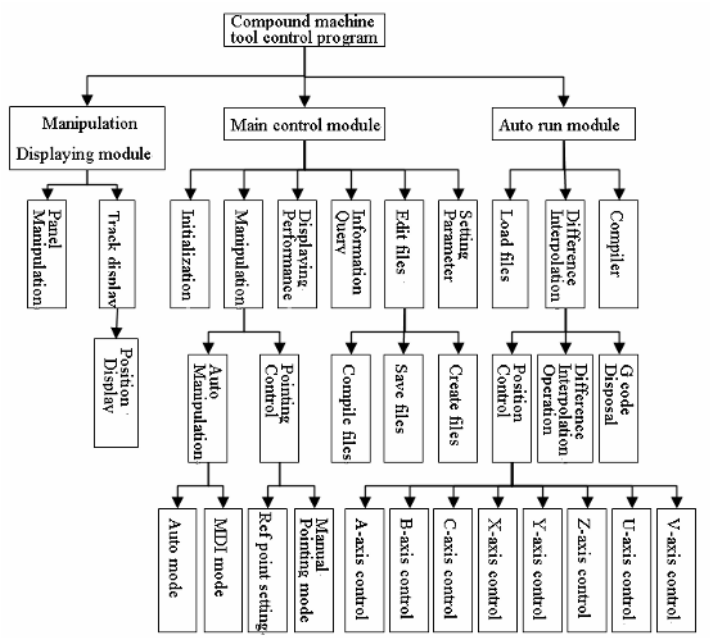

Fig. 6. control program logic diagram

The main control module should accomplish many complex tasks, such as the initialization, the NC programs input, edit&compiling, setting parameters and operation. So it is needed to design a series of unattached function program modules, and furthermore, the same program module has the different module contents under the different control methods.

The control program is designed based on the Windows operating system, so it has the multi-task coordinated ability. In the program, user manipulative performance is composed of many windows and each of them executes one task. And the functions are realized competitively in the different windows. The states of each task are managed by the management program[5][6]. The main function of main-menu performance is monitoring, performance management, function controlling and system managing. The main function of main-menu performance is monitoring, performance management, function controlling and system managing.

The control part is the vital part of the whole software, and it determines the qualification of the control system. The flow chat of the whole software is shown in fig.7. After initialization of the system, the reference point setting and etc., the SERCOS-Master's drivers can be used for operating its interface card. And SERCOS-Master interface card supplies the difference interpolation functions which are available for movement control.

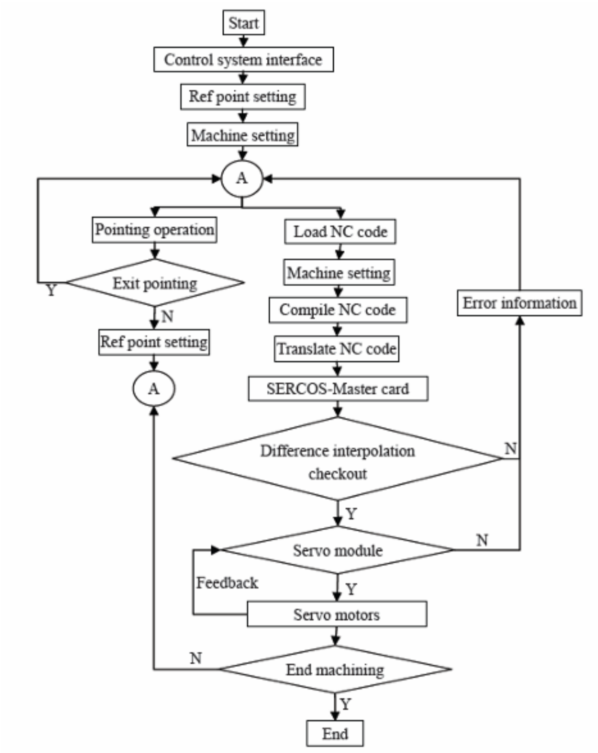

Fig. 7. The flow chat of the whole software

5 Measurement

Positioning accuracy of the machine tool six axes are measured by ML10 laser interferometer made by the Renishaw company. The measurement results are analyzed by the corresponding analysis software. The following results are obtained.

Overall Accuracy, $A = Max(x_i - x_j)$.

Positive Repeatability Accuracy, pos rep=max pos-min pos.
Reverse Repeatability Accuracy, rev rep=max rev-min rev.
Bidirectional Repeatability Accuracy, $B_j = x_i \uparrow - x_j \downarrow$.

The analysis results are shown in table 1. The max overall accuracy is 301.8μm, the max positive repeatability is 277.4μm, the max reverse repeatability is 150.7μm, the bidirectional repeatability is 367.6μm. From the results it is found that the control system can satisfy the machine tool's accuracy request.

Table 1. Positioning accuracy of six axes

motion axes	Overall Accuracy(μm)	Positive Repeatability (μm)	Reverse Repeatability (μm)	Bidirectional Repeatability (μm)
X axis	156.2	64.7	0.7	141.9
Y axis	251.5	20.9	20.9	34.8
Z axis	39.1	47.8	9.5	367.6
U axis	301.8	245.5	150.7	264.7
V axis	264	277.4	37.4	345.3
W axis	39.1	47.8	9.5	307.6

6 Conclusions

1. Based on the CH-2010, the control system of the lathing and welding compound NC machine tool is designed, which has many fine characteristics, such as good expansibility, general-purpose functions and friendly user interface.
2. Multiple machine axes are moved simultaneously, and the control system can realize the auto control of the lathing and welding processing. It can satisfy the lathing and welding combined machining require.
3. The control system can realize Off-line Programming and test show that the system run credibility and can fulfill the control accuracy requirement.

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