Motion Controller and the Application of PMAC in AC Servo CNC System

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Abstract –The concept and sorts of motion controller were introduced in this paper, the features of PMAC motion controller was explained, and the make-up of the numerical control system based on MINI-PMAC, PC and AC Servo Driver was discussed in detail including hardware structure and software designing. Then a development example of experiment was shown. Servo compute and control in the CNC system are both performed by PMAC，while PC and other general interfaces act as terminals, this structure offers more flexibility and can be used in a wide range of applications.

Keywords - Motion controller, PMAC, CNC, AC Servo driver, PEWIN Software

I. INTRODUCTION

A typical motion control system mainly consists of superior computer, motion controller, power driving device, motor, feedback detecting sensor and controlled object, as shown in Fig. 1.Motion controller is the centre of the control system and it takes the central logic control unit as the core, takes the sensor as the component sensitive to feedback signal and takes the motor as the controlled object. The main task of the motion controller is to perform necessary logic and mathematical operations according to signals from the sensor and the requirements of control task, then provide appropriate control signals for driving device.

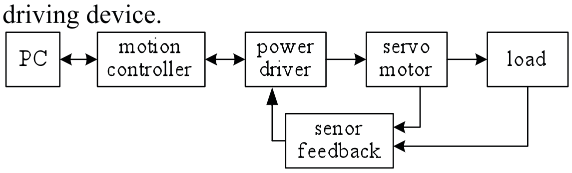

Fig. 1 Constitution of a typical motion control system

II. CLASSIFICATION OF MOTION CONTROLLER

Motion controllers can be classifed in different ways. According to the structure, motion controllers can be divided into three forms:

A. Computer standard bus based Motion controller

This kind of motion controller has open architecture and is independent from computer.It could combine with computer by many different bus such as ISA interface, PCI interface, VME interface, RS232 interface and USB interface. Most of theses motion controllers use DSP or microprocessor chip as CPU and could perform functions including motion planning, high-speed and real-time interpolation, servo filter control, servo drive and standardized general interface to external I/O. They also provides powerful motion control software libraries such as C language motion function library, Windows DLL dynamic-link library and etc.So users could develop their own application softwares on DOS or Windows and create various control systems according to their own requirements. Programmable Multiple Axes Controller PMAC produced by American Deltatau company is a representative of this kind of motion. Similar products include TRIO from British Allworld company, GT series from Googol Technology (Shenzhen) Ltd. and NI series from American NI company.

The motion controller and PC make up a master-slave control structure: PC is responsible for managing human-computer interface and monitoring the operating state of the control system in real time, and the motion controller completes all the details of the motion control task such as producing pulse and direction signals, calculating the trace, detecting home and limit signals. The advantage of such a structure is combining PC’s ability to process information and motion controller’s ability to control motion trace. CNC systems with open architecture based on motion controller are widely used in equipment automation in manufacturing industry. This paper introduces the performance characteristics of PMAC and designs a PMAC-based CNC system then gives a development example.

B. Software based open motion controller

Software based open motion controller provides users with a great deal of flexibility.The motion control softwares are all installed in the computer, and the hardware only provides standardized general interfaces to computer,to servo drivers and external I/O,as computer could be installed with various sound cards, CDROM and corresponding drivers. With the support of Windows and other operating systems, users can obtain desired control functions and develop various high-performance motion control system.So this motion controller provides more choice and flexibility for the users.

C. Embedded motion controller

This is a motion controller in which a computer embedded and it could operate independently. This motion controller also communicate with computer through computer bus. It is a variation of the bus based motion controller in essence. In the application it connects to a superior computer or a control panel through field communication interface such as Industrial Ethernet, RS485, SERCOS and Profibus. In addition,embedded motion controller can be provided with floppy and hard disk drivers,even get remote diagnosis through the Internet, such as Smart-Controller from American ADEPT company, GU embedded motion control platform series products from Googol Technology (Shenzhen) Ltd..

III. Hardware Structure Of CNC System

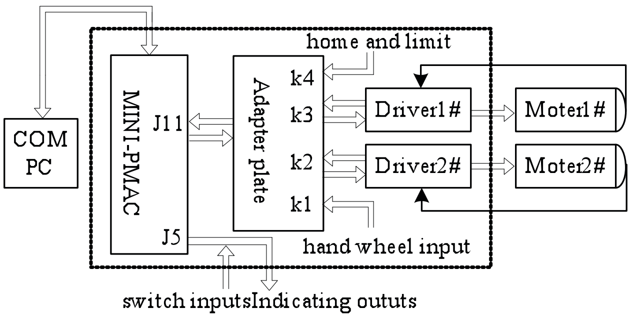

Fig. 2 Structure diagram of PMAC-based CNC system

The CNC system consists of superior computer, Programmable Multiple Axes Controller MINI-PMAC, adapter plate, servo drivers and AC servo motorlt in hardware. It could perform various montion control functions by using superior and inferior softwares. Fig. 2 shows the structure of the system. MINI-PMAC, adapter plate and drivers are all assembled in a cabinet, so the system could work offline.

A. PMAC

PMAC from Deltatau company is a multi-axes, multi-channel, open motion controller. It is based on industrial computer and could control up to 8 axes simultaneously. It uses high-performance digital signal processor DSP5600X produced by Motorola as the CPU and could combine with various computers, amplifiers, motors and sensors to perform different functions.

PMAC is a complete computer in its own competence. It could process stored program independently of the operating system and could define task priority, working like a realtime multitasking computer.Even if PMAC is controlled by a host computer, their communication is between two computers, rather than communication between a computer and peripheral. From the processing time and the complexity of the task switching, PMAC's ability to process multiple tasks simultaneity (according to the priority) reduces the burden of the computer.

There are two PMAC familis : PMAC1 and PMAC2. Each can be divided into four hardware forms PMAC-PC, PMAC-STD, PMAC-LITE, PMAC-VME according to communication bus. MINI-PMAC used here is PMAC-PC form of PMAC1 which can control two axes simultaneously. It has ISA bus or RS-232/422 communication port for bus communication or serial communication. MINI-PMAC mainly contains the following interfaces:

- Jl (JDISP): display interface, l4 pins, used to connect a simple LCD screen to display the location and speed of shafts.
- J3 (JTHW): multi-way DIP switch, 26 pins, to provide 8-in and 8-out general I/O in TTL level, used to expand input and output points or used as general I/O directly.
- J4 (JRS232): serial communication port, l0 pins, to provide serial communication interface RS232 to the host coputer.
- J5 (JOPTO): general digital input and output port, 34 pins, to provide 8-in and 8-out general I/O in TTL level.
- J7 (JS1): l6 pins, to provide interface to A/D conversion attachment ACC-28.
- J8 (JAUX): auxiliary interface, l6 pins, to receive 0-10V analog input, pulse direction output, location comparing signal and so on.
- Jl1 (JMACH): main working interface, 60 pins, including the control signal output, servo enable signal output, home limit and ervo alarm signals input, encoder feedback signal input and power interface.
- TB1: interface to external power,to supply power for motion controller when MINI-PMAC is used alone

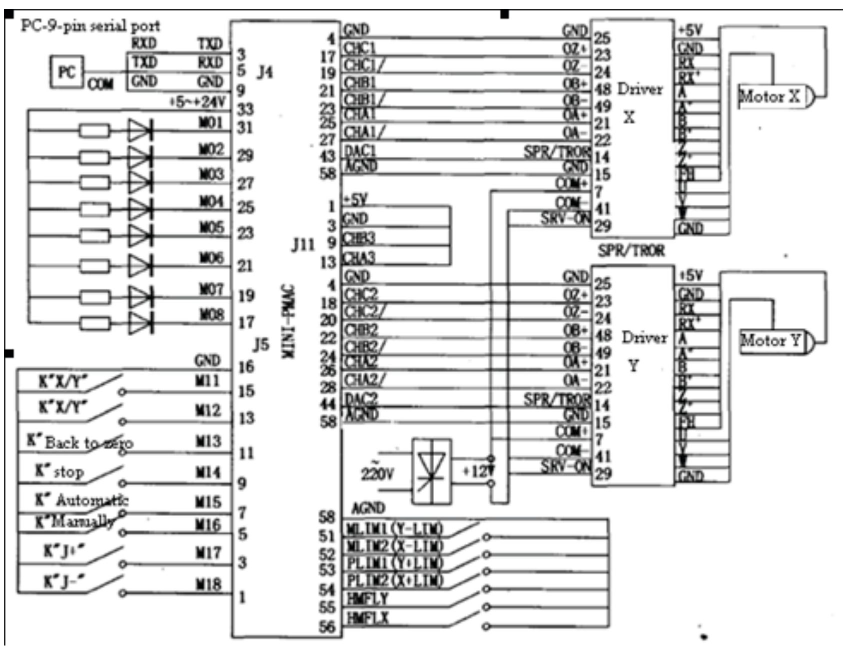

Fig. 3 Hardware structure of PMAC

B. Servo system

J11 interface of PMAC connects to servo drivers through adapter plate. Driver MS-DA023A1A applis to MSM small inertia motor and uses 200V three-phase AC voltage.The speed analog output of PMAC connects with AC servo drivers who drive AC servo motors. Encoder was installed on the motor to detect the feedback.

The performance of servo system could be regulated by adjusting PID adjuster on the PMAC,the speed feedforward, the acceleration feedforward. If the the proportional coefficient is greater, the rigidity of the system will be better.However there will be greater error caused by over reaction if the proportional coefficient is too great,even wores the motor may run in open loop. Adjusting integral coefficient can eliminate the steady-state error in the system. Adjusting differential coefficient provides the damping that system needs to maintain the stability. The role of adjusting the speed feedforward is to reduce the following error caused by damping which is proportional to the speed. The role of adjusting the acceleration feedforward is to reduce or eliminate the following error caused by the system inertia which is proportional to the acceleration.

When regulating performance of the servo system,adjust the AC servo drivers' parameters first. After the motion of the AC servo motor meets some requirements, adjust PID parameters on PMAC to achieve the best performance.

The schematic diagram of the entire system is shown in Fig. 3. As shown, J4 is communication interface to computer, J5 is general digital port for 8 switched inputs and 8 TTL level outputs, namely, panel switch inputs and diode outputs, and Jl1 includes four parts: (1) control of AC servo driver X, (2) control of AC servo driver Y, (3) hand wheel input, and (4) limit and home input. DAC1 provides speed analog signal for drivers and CHA1～CHC1 receive the feedback of encoder on servo motor.

IV. WARE DESIGN AND RELIZATION

A. Introduction of PEWIN

PEWIN is the development tool produced by Deltatau to establish and manage application system for PMAC.It provides a friendly PMAC-oriented serial port terminal interface and a text editor uesd for writing motion program and PLC program. In addition, PEWIN provides a series of interfaces for PMAC configuration and monitor, including motor driving interface, variable setting interface, coordinates setting interface, windows for observation of PMAC variables and state registers, etc.

PEWIN takes full advantage of the Windows operating environment:

- Text editor's function: cut, copy and paste;
- A good graphical interface to communicate with and operate PMAC;
- Dealing with thousands of I, P, Q and M variables of PMAC flexibly;
- A window to display motor state,coordinates and the overall state in real time;
- A window to display the location, speed and fault of all the motors in the system;
- A variety of ways to adjust the PMAC system;
- A interface for data collection and mapping;
- Deagnostic program to identify and remove faults of motors and drivers;
- Displaying the real time status of PMAC interfaces;
- Coping Variables between different motors;

B. Initialization of the system

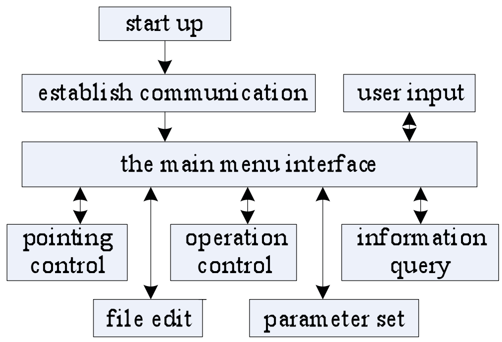

Fig.4 Structure of motion control software

Fig. 4 shows software structure of the CNC system. Start up the PEWIN program first, power on the whole CNC system, establish the communication with PC, enter the main menu interface, and then complete pointing control and other operation.

After entering the menu and command window, users can query the information and set parameters according to their own needs to initialize the PMAC.

C. Motion program and PLC program

PMAC can support 256 motion programs and each could be executed in any coordinate at any time. A motion program could call any other motion program as subroutine. PMAC motion language is similar to BASIC and other high-level language and writing motion program could achieve motion and compensation such as straight-line hybrid motion, trigger motion, circular interpolation motion, PVT mode motion ,Spline motion, synchronous motion, cutting tool radius and axes transformation matrix.

PMAC has 64 PLC programs which are executed non-synchronously. PLC programs have the same logic structure with motion programs but have no motion statements.Their working principle are similar to PLCs which are widely used in the industry control fields.They both execute commands in cycle. But differently,PLC programs of PMAC use program mode similar to BASIC and other high level languages,so they are more flexible and convenient, easier to storage and the execution speed is faster than ordinary PLC. PLC programs are used to monitor analog and digital inputs, set outputs, send messages and monitor motion parameters and could access all the variables and I/O of PMAC. They are powerful attachments for the motion controller.

In addition to the above standards for program writing and executing, PMAC could execute machine tool RS-274 (G code) program, call G, M, T and D code as a routine of subprogram.

D. Adjust PID parameter using PEWIN

PEWIN provides a simple method to regulate the PID parameters-speed/acceleration feedforward parameters-NOTCH filter parameters.It could execute simple standard motion orders and collect response data for statistical response calculation.Make judgments according to the obtained response graphics, adjust and optimize PID parameters,finally achieve reasonable PID parameters, good steady-state and dynamic performance and minimum following error. PID parameters could be adjusted through step response and sine wave response.

Enter the PID-feedforward adjustment interface, adjust the servo loop PID parameters through step response manually, maintain these parameters unchanged, and adjust the feedforward through sine wave response.

Fig.5 shows the step response afetr parameter adjustment,1 is the order location curve and 2 is the actual location curve. Fig. 6 shows a good sine wave response curve after parameter adjustment, 1 is the actual speed curve and 2 is the order speed curve, 3 is the following error curve.According to the above principle,the speed and acceleration feedforward could be adjusted to achieve the best dynamic performance of the system.Among these adjustable parameters, I130, I131, I132, I133, I134, I135 are most critical to the performance of the system and they have optimum values corresponding to the best system performance. The change in any one parameter will affect the performance of the entire system.

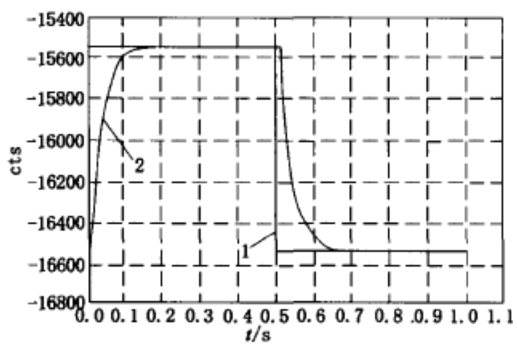

Fig.5 Step response curves

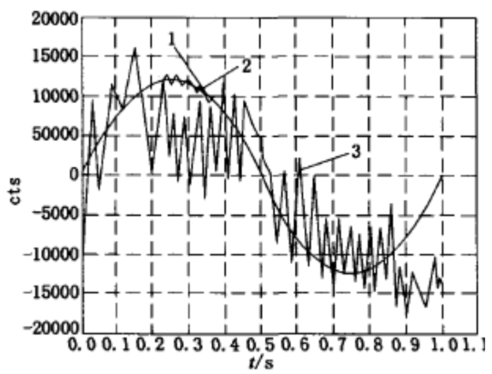

Fig.6 Sine wave response curves

V. A Development Example

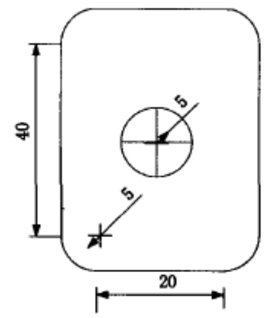

Fig.7 A trace example

This program is an application example of arc and line interpolation mode. As shown in Fig.7, it draws a rectangle with rounded corners in the X-Y plane, draws a circle in the center and uses an output signal to indicate the beginning and end of the motion.

```
#1->10000X        ; Define coordinate axis
#2->10000Y
A
CLOSE
DELETE GATHER
OPEN PORG 2
CLERA
I13=6             ; Arc section time
NORMAL K-1        ; Appoint  X-Y plate
RAPIDX15Y30       ; Fast motion mode
CIRCLE2           ; Anti-clockwise circle
X15Y30I0J0
DWELL1000         ; Stop for 1 second
RAPID
X10Y5
I13=0
M7=1              ; Turn on output (indicator light 7)
LINEAR            ; Linear interpolation mode
FI0               ; Define speed 1cm / s
X30Y5             ; Lower side
CIRCLE2           ; Lower-right round corner
X35Y10J5
LINEAR
X35Y50            ; Right side
CIRCLE2           ; Upper-right round corner
X5Y55I-5
```

```
LINEAR
X10Y55              ; Upper side
CIRCLE2             ; Upper-left round corner
X5Y50J-5
LINEAR
X5Yl0               ; Left side
CIRCLE2             ; Lower-left round corner
X10Y5I5
DWELL1000           ; Ensure the position
M7=0                ; Turn off output
RAPID
X0Y0                ; Return to zero
CLOSE
```

VI. CONCLUSION

This paper designs a PMAC-based open CNC system. The system has advantage of short development cycle, low cost,more interpolation axes and high control accuracy. PMAC is the core of the CNC system and completes all the servo computation and control. PC and other general interfaces are terminals of the entire system. This open architecture offers more flexibility and can be used in a wide range of applications.

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