Reformation and Commissioning Research on Closed-Loop Control of Y Axis CNC Milling Machine

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Abstract: Considering its working stability, semi-closed loop control is usually used in Mid-range CNC machine tool, but Processing quality of the product is Seriously affected by wear, hot variant, screw error and backlash of machine driven system. In order to improving machining precision, reformation processing on closed-loop of Y axis in THWMZT-1B CNC milling machine is introduced, such as connecting and installing hardware, setting parameters and backlash compensating. Commissioning results have shown that repeated positioning accuracy got 0.01mm, pleased result was got.

Keywords: Backlash compensating, closed-loop control, grating scale, parameter.

1. INTRODUCTION

X, Y, Z axis of THWMZT-1B type CNC milling machine were all controlled by means of semi-closed loop. Photoelectric encoder mounted on the shaft end of the motor can real-timely read motor coaxial rotating speed signal, real-timely monitor motor angular displacement. Without monitoring the drive chain after the motor shaft, loss of precision caused by screw error, thermal deformation and backlash can't be controlled [1-3]. At present, in the mid-range or high-end CNC machine tool, the feed axis servo control circuit generally adopts the semi closed loop or closed loop two forms. In order to meet the needs of high-grade CNC equipment for repairing personnel that be familiar with the installation and adjustment and the conversion between the semi closed loop and closed loop control and debugging, to improve the machining precision, Y axis of THWMZT-1B CNC milling machine is be reformatted by closed loop control. The control block diagram is shown in Fig. (1), the closed-loop control system is that the actual location will be detected by the linear position detection device (such as a grating ruler) directly installed in the moving parts (such as table), and then feedback into the CNC system, be compared with the machine position Command, control the moving parts move with the comparison of the difference, until the difference is eliminated to stop moving. FANUC servo system is a full digital servo system, the axis card system is a sub system of CPU, which completed PID servo control of position, velocity, current, and that PWM control signal is transmitted to the servo amplifier, velocity of the servo motor is changed by frequency conversion. It mainly consists of the following parts.

1.1. Position Control Portion

Position control is the core part of the servo system, it includes interpolator, position error register and reference counter. Interpolation algorithm that position command will be changed into regular pulses, these pulses is input to the position error register with the motor feedback pulses whose phase is opposing, the result having direct impact on the speed of the motor in position error register is equal to the command position subtracting the actual position of the motor is completed in interpolator. The reference counter is used to machine zero, details see parameter setup part.

1.2. Speed Control Part

Speed control being used for controlling motor speed is the intermediate loop of PID control, its instructions is from the output of the position control, its feedback is from the motor actual speed.

1.3. Current Control Part

Current control being used for stabling current of the motor is inner loop of servo control, its input is from the output of speed control, its feedback is from the motor current. In addition, the three-phase current of AC motor is converted in the part.

Because the position detection of the full closed loop system contains all the error feed drive chain, such as clearance of ball screw and guide rail pair, the error is compensated, which can reach high control precision, the positioning accuracy can be within ± 0.001 mm.

2. HARDWARE CONNECTION

2.1. Selection of Grating Scale

A FAGOR MKX scale was selected, the scale is serial and incremental, its zero pulse spacing is 50mm, its
resolution is 0.004 mm, quadruple the frequency of CNC, the actual resolution is 0.001 mm.

2.2. The Separate Detector Interface Unit Module Mounted

As shown in Fig. (2), the separate detector interface unit module is mounted on the left side of the I/O link module, and the appropriate space is kept between them to facilitate heat dissipation, their top surfaces are in the same horizontal line.

2.3. Grating Signal Feedback Wire Welding

1). As shown in Fig. (3), the grating scale extension line (green) DB15 pin serial interface was replaced with 20P high density plug matching separation and detection unit module interface. Each pin of scale, extension line and module serial connector is defined as follows:

2). Confirm the correctness of the pin welded, the welded serial interface was plugged in JF102 connector of the separation module.

3). Make a connection from the COP10A connector of Z axis driver to the COP10B interface of separation module with cable.

4). The 24V power connector whose one pin is 24V, the other pin is 0V was done, the connector was plugged into CP11B connector of separation module.
Table 1. Pin of scale, extension line and module serial connector defined.

<table>
<thead>
<tr>
<th>SCALE</th>
<th>EXTENSION LINE</th>
<th>MODULE CONNECTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIN</td>
<td>SIGNAL</td>
<td>COLOR</td>
</tr>
<tr>
<td>1</td>
<td>A</td>
<td>Green</td>
</tr>
<tr>
<td>2</td>
<td>/A</td>
<td>Yellow</td>
</tr>
<tr>
<td>3</td>
<td>B</td>
<td>Blue</td>
</tr>
<tr>
<td>4</td>
<td>/B</td>
<td>Red</td>
</tr>
<tr>
<td>5</td>
<td>I0</td>
<td>Grey</td>
</tr>
<tr>
<td>6</td>
<td>/I0</td>
<td>Pink</td>
</tr>
<tr>
<td>9</td>
<td>+5V</td>
<td>Brown</td>
</tr>
<tr>
<td>11</td>
<td>0V</td>
<td>White</td>
</tr>
<tr>
<td>15</td>
<td>Shield</td>
<td>15</td>
</tr>
</tbody>
</table>

Fig. (4). The overall installation schematic diagram.

2.4. Mount Scale and Position Adjustment

Each sheet metal combination and installation method sketch the details are as follows:

In Fig. (4), every symbol is expressed as follows:
1--- the milling machine bed;
2--- the scale;
3--- the bracket 1;
4--- the bracket 2;
5--- the fixed bracket of the reading head;
6--- the scale shield;

Specific requirements for installation:
(1) Fix the scale bracket 1. Align the two central lines by finding the central line of the Y axis travel and the scale bracket 1, and the centers of two holes being used for fixing bracket 1 is located 25 mm at the bottom of the scale protection cover.
(2) Unplug the power line of Y axis and manually shake the Y axis, verify that the maximum height error between the ends of the scale bracket 1 by using a lever indicator is less than 0.10 mm.
(3) Fix the scale and the bracket 2. Measuring the equal height and parallelism of the scale body by using the lever indicator, the two maximum errors of accuracy requirements must be less than 0.02 mm.
(4) Fix the reading head of the scale. Verify that the space between the reading head and the scale body is about 2.0 mm. The screws fixed the reading head are in the middle of the U shaped hole on the fixed bracket of the reading head. At the same time, need to ensure that the reading head relative to the scale body are parallel, not to tilt to the other direction, and thus probably determine the location of the fixed bracket of the reading head on the saddle.
(5) Fix the scale shield. When mounting the shield, need to cover the entire scale and not affect the movement of machine tool.
(6) All sheet metal parts must to be center of the installation, in order to facilitate the subsequent precision adjustment.
3. PARAMETER SETTING

Because the closed loop control system contains these large inertia link such as screw, nut and the work table of the machine tool, these nonlinear and unstable factors such as screw tension compression, torsion and friction damping characteristics and gap appear in the process of Commissioning, if matching parameters are not appropriate, that will cause system oscillation and result in the machine tool work instability. The premise of correct control of closed-loop system is that CNC output command pulse number corresponded any moving command must be equal to actual feedback pulse number. These parameters matching command pulse and feedback pulse equivalent have CMR, DMR and the reference counter capacity. Setting the reference counter capacity parameter (PRM1821) is mainly used for grid mode back to the origin. The FANUC system back to the origin is in fact that finding physical grid, and then moving one “offset” form a grid, and take the grid as the zero point. According to the reference counter capacity, one grid pulse (electrical grid) is overflowed every pulse number arriving at setting of PRM1821, the grid pulse and the physical grid that one signal is sent by photoelectric encoder taking a turn offset the setting of PRM1850, take it as a reference grid back to zero, as shown in Fig. (5). Because “zero reference pulse” is specified by grid, and the grid is determined by the reference counter capacity, when the reference counter capacity setting error, the electrical grid “spillover” no rules, will cause every time back to zero position is not consistent, i.e., back to the zero point is not correct. Setting servo parameters is that reasonable PID control parameters are given, to achieve the optimal control performance. In the initial stage of servo debugging, need to set these parameters by entering the “parameter setting support” picture “servo settings” menu.

The scale connector was plugged into JF102 connector of separation module. In order to bring the separation module into effect, PRM1815.1 must be set to “1”, the connector number M1 of the separation module must be set to “2”. The minimum movement unit of THWMZT-1B CNC milling machine is 0.001 mm, its screw pitch is 5 mm/r, motor and screw were directly connected through the coupling. In order to make the calculation and control convenient, CMR is usually set to 1, then PRM1820=2*CMR=2; flexible gear ratio N/M=1/1 i.e. PRM2084=1, PRM2085=1; measurement device for detecting resolution / minimum movement unit = 0.004/4 /0.001=1/1; The position feedback pulse number per motor revolution PRM2024= The amount of movement per motor revolution / minimum movement unit =5/0.001=5000, the reference counter capacity PRM1821= the scale zero pulse spacing / minimum movement unit =50/0.001=50000, and set the following:

1. The detecting element of full closed loop position control system needs to connect the interface unit of the separation module, the interface unit and CNC are connected by FSSB bus, which belongs to one of the FSSB substation. In order to establish correspondences relations between the drive letter and the interface unit and related servo function, the Y axis connector number M1 of the separation module in “axis setting” picture must be set to “2”, as shown in Table 2.

Table 2. M1 of Y axis setting.

<table>
<thead>
<tr>
<th>AXIS</th>
<th>NAME</th>
<th>AMP</th>
<th>N</th>
<th>M</th>
<th>1- CS</th>
<th>INDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X</td>
<td>A1-L</td>
<td>0000</td>
<td>0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Y</td>
<td>A2-L</td>
<td>0000</td>
<td>0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Z</td>
<td>A3-L</td>
<td>0000</td>
<td>0000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. The 1815 #1 parameters of Y axis is set to 1, in order to bring the separation module into effect, as shown in Table 3.

3. Set the feed gear of Y axis, the numerator and the denominator are respectively set to 1, the position feedback pulse and the reference counter capacity of Y axis are respectively set to 5000, 50000, as shown in Table 4.

4. CLEARANCE COMPENSATION

The matching precision requirement of the mechanical transmission chain is relatively high for full closed loop control, because of the influence of the mechanical driving system gap, ball screw and the machining error and other factors, there are always some errors existing between the actual positioning and CNC theory position of coordinate axis, especially in the case of long-term use of machine tool, with the ball screw nut pair wear increasing, the reverse gap phenomenon is more obvious. If the gap is generally greater than 0.05 mm-0.10 mm, which can produce a servo
oscillation, occur high-frequency noise when the machine tool works, so that the machine tool is unable to make the processing normal [3]. In order to improve contour precision and positioning accuracy and repeated positioning accuracy in the machining process, some compensation is required. PR1800.4 is usually set to 0, so that the fast/cutting feed respectively compensation function is invalid, then setPR1851 (cutting and manual continuous feeding reverse gap). For example of No. 5 machine tool, when the Y axis adopts the semi closed loop control and each axis is without backlash compensation, reverse gap of X, Y, Z were respectively 0.05 mm, 0.07 mm, 0.06 mm. After closed loop transformation of the Y axis by using scale, the backlash compensation PR1851 of X, Y, Z axis were respectively set to -10, 50, 90, through repeated measurements, it shows that repeated positioning precision of the machine tool can reach 0.001 mm.

Table 3. PRM1815#1 setting.

CONCLUSION

The machining accuracy was improved by the Y shaft semi-closed loop transformation for the closed-loop control taking scale as the detecting element, and by setting parameter and backlash compensation. This scheme can be applied for each axis closed loop transformation of FANUCi NC machine tool, also can be used reversely the closed loop transformation for the semi closed loop, provides a new detecting and maintaining method for NC maintenance personnel. Closed loop control can improve the machining precision, but the reverse error is not stable after running for a period of time, must be adjusted periodically.

Table 4. Servo setting.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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Declared none.

REFERENCES