Control system of stepper motor based on roundness and cylindricity measuring virtual instrument

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Abstract
The control system uses LABVIEW as the software development platform. The system includes ADLINK motion control card PCI-8134, LEETRO stepper motor drivers DMD 402A, and tables with LEETRO DM4240A stepper motors. The system uses ADLINK PCI-8134 to send stepping pulse signal PUL and direction level signal DIR to control the stepper motor’s rotation angle and direction, achieving the motor’s positive and negative rotation, acceleration, constant speed and deceleration, then achieving the radial motion of table’s Z-axis slider along the surface of the measured part, the axial motion of X-axis slider along the surface of the measured part and the spindle rotation for the measurement of roundness and cylindricity.

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1. Introduction
The stepper motor is mainly used in open-loop control system. Because of its simple structure, reliability, well controlled, anti-interference ability, no accumulated error and direct digital control, the stepper motor is widely used in automatic control systems. In the design of stepper motor control system, the traditional method is to use logic circuits or single chip to control stepper motor, conditioning the

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input analog signals and converting the signals into digital signals by the A/D, then a microprocessor in accordance with the function requirement does necessary analysis and processing on the collected data, and then the processed data is stored and displayed or output the analog signals converted by D/A. But the traditional system has problems such as slow sampling rate, low control precision, long development cycle and Poor portability. The use of virtual instrument graphical programming software LABVIEW to control stepper motor has advantages such as simple hardware structure, simple programming, friendly interface, the portable program. In this paper LABVIEW is used to develop a three-axis stepper motor control system. So the DM4240A two-phase hybrid stepping motor and DMD402A stepper motor driver produced by LEETRO are selected in this project.

2. Stepper motor control system

2.1. Hardware components

Stepper motor control system hardware, shown in fig.1, consists of computers (with LABVIEW 8.6 applications), ADLINK 8134 motion control card (32-bit PCI bus, can control up to 4 axis), LEETRO DMD402A stepper motor driver (with chopping frequency of 20 KH, drive current range of 0.25 A ~ 2 A), LEETRO DM4240A stepper motor (with stepping angle of 1.8°, phase current of 0.85 A, static torque of 16 N.cm, moment of inertia of 57 g.cm², weight of 240 g) and self-made mini-table body. Because only three axes on the workbench is needed to be controlled, so only three pins of motion control card is used, shown in fig.1.

Fig.1. Schematic of stepper motor control system

2.2. Connection Method

In the device, the stepper motor is controlled by single-ended connection. It should be aware of as following when the motor is linked to the motion control card ADLINK PCI-8134 by direction, pulse and ground control Etc. Wiring method Shown in fig.2

Fig.2. Wiring Methods
Jumpers of PCI-8134 motion control card: Motion control card’s j1-j8 connect to the 2-3 terminals. Motor driver’s resistance should not be less than 4.7 kΩ. Because the current through the motion control card must not be more than 20 mA, so a 4.7 kΩ resistor should be in series.

2.3. Software Development Tools

The system software is developed by LABVIEW 8.6. The program prepared by LABVIEW platform known as the VI, each of which includes the front panel and rear panel. The front panel, which is the human-computer interaction interface, provides a large number of graphical display controls and data input controls, mainly to complete the initial data input and results display. Block program of rear panel consists of ports, node, frame and connection. Ports are used to transmit data. The nodes are used to achieve the functions and call the function. The frame is used to implement structured programming control. Connection presents stream of data during the program execution.

2.4. Stepper motor speed and position control

As ADLINK PCI-8134 motion control card can not directly match LABVIEW software, the motion functions provided by manufacturers can be called only after it is imported into the user library. Motion function library contains a wealth of motion functions, in the paper we select the Start-tas-move() movement module to control the motor’s speed and position. The front panel shown in fig.4

![Fig.3. Front panel of motor’s speed and position control](image)

The number under axis is the number of the axis which is under controlled. The relationship of axis number with the axis on the workbench is determined by the specific connection. ExistCards means the exist numbers. max-vel means the maximum running rate of the motor. tr-vel means the initial rate of motor. Tsacc means motor’s accelerating time in the curve segment. Tsdec means the motor’s decelerating time in the curve segment. Tlacc means the motor’s accelerating time in the straight line. Tldec means the motor’s decelerating time in the straight line. pos means the motor’s running distance. Error means errors of motor shown during running. Error Out means the initialization state of the board.

The reason for the Start-tas-move() movement module is selected to control the motor’s speed and position is that the movement module can give the S-curve motion profile to motor as its speed curve, shown in Figure 4, which can reduce the impact of the motor and extend the service life of the motor.
Parameters in fig. 4 meanings: max-vel is the maximum rate; tr-vel is the initial rate of motor; Tsacc is motor’s accelerating time in the curve segment; Tsdec is the motor’s decelerating time in the curve segment; TLacc is the motor’s accelerating time in the straight line; TLdec is the motor’s decelerating time.

The relationship between them, such as the following formula:

\[
\begin{align*}
\text{max} \_ \ \text{vel} &= \text{str} \_ \ \text{vel} + \text{accel} \cdot (T\text{Lacc} + T\text{sacc}) \\
\text{str} \_ \ \text{vel} &= \text{max} \_ \ \text{vel} + \text{decel} \cdot (T\text{Ldec} + T\text{sdec})
\end{align*}
\]

In the formula, accel and decel represent the acceleration and deceleration. Parameters are set on the software front panel according to the relationship between the rate and time, implementing the motor by open-loop control.

2.5. stepper motor’s forward and reverse control

Forward and reverse of the stepper motor are controlled by the Boolean control variable, switched to the forward position, the forward signal is outputted or switched to reverse position, reverse signal is outputted.

In the fig. 6, ExistCards means the exist card’s number, axis is the number of the axis which is under controlled. Tr-vel means the initial rate of motor, max-vel means the maximum running rate of the motor, pos means the motor’s running distance and Error Out means the initialization state of the board.
Corresponding program diagram shown in Figure 6, the design steps are as follows:
Initialize the card number and axis number;
Feedback initialization error;
Display the motor’s state;
Determine the forward and reverse signal;
Set the initial rate, maximum rate and distance of motor movement;
Movement back to the origin of coordinates when the movement is finished;
Display the errors;

3. Experimental conclusions

In this paper, the stepper motor’s control system is functional unit of the roundness and cylindricity measuring virtual instrument. By calculating the relationship between the sensor’s acquisition rate and the stepper motor’s speed, achieving the stepper motor’s open-loop control, finally getting the collection of the reliable data and reliable operation of subsystems, ensuring the implementation of the system function. The control program of the motor is easy to be modified and expanded, portable to the other test system based on the LABVIEW software development platform. As the LABVIEW is used to develop the stepper motor control system, we have a lot of advantages, such as the software programming is simple, man-machine interface is friendly and easy user control.

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