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Design of Multi-axis Synchronous Control System for the Multi-dimensional Mirror Detection Device

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Abstract

On some special occasions, professional lenses need to be used, and these professional lenses not only require complex and superb manufacturing processes and technologies but also put forward higher requirements for the detection technology of lenses. In the lens surface detection technology, a multi-dimensional reflection technology can be used, and this multi-dimensional reflection lens detection device has high requirements on the synchronization accuracy during the movement process. Programmable Logic Controller combines the concept of the virtual axis and encoder axis to provide stable, fast response, high-precision speed, and position control for the interferometer lifting platform part of the device.

Keywords

Virtual Axis; Encoder Axis; Synchronization Control; Bus PLC.

1. Introduction

The multi-dimensional mirror detection device is a high-precision system that requires multi-motor coordinated control, and a certain part of it needs to achieve high-precision synchronous control. This article takes this as a starting point to introduce the multi-axis synchronous control system based on DVP15MC11T.

The traditional mechanical synchronization structure is realized by adding physical connections between the moving shafts, which often requires a high-dynamic motor to transmit energy to the target machine through gears, chains, belts, need other structures, but the traditional mechanical synchronization structure cannot meet the requirements. The project needs it, so this paper adopts an electrical synchronization method. This paper uses a virtual electronic spindle as a core controller and uses the required control motor as a sub-unit to control the synchronous movement of the corresponding motion axis to reach the target position[2][3].

2. Part of the Mechanical Structure

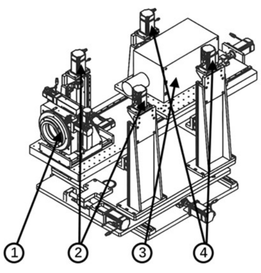

Figure 1. Interferometer and CGH adjustment frame

①CGH adjustment frame ②motor 9, 10 ③optical instrument ④motor 7, 8

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As shown in Figure 1, When the rear row of the interferometer lifting platform (motors 7 and 8) moves, it will drive the optical instrument to rise or fall to realize the pitching action of the entire platform.; When the front row and the rear row (motors 7, 8, 9, and 10) of the interferometer lifting platform act together, the entire platform is driven to rise or fall; The light emitted by the optical instrument passes through the lens clamped by the CGH adjustment frame disc and finally reaches the mirror surface of the target lens to detect the quality of the mirror surface.

Because the whole set of equipment is relatively expensive, the production process requirements are high and the production time is long, the position error during the operation of these motors and after the operation is relatively small, which has higher requirements for the control accuracy of the entire equipment.

3. Control Hardware Design of Multi-dimensional Mirror Detection Device

3.1 Main Hardware Introduction

To achieve high-precision synchronous control of the multi-dimensional mirror detection device, high flexibility of the control system, safety and reliability, and localization of a complete set of equipment, the control scheme in this paper uses Delta's bus-type PLC (DVP15MC11T) and Delta's servo motor to form a high-precision position. with a speed control system. The motor forms a high-precision position and speed control system. Compared with the traditional pulse-type PLC, the bus-type PLC has a faster communication speed and can realize isochronous synchronization in a true sense. The bus-type PLC has higher reliability, anti-interference ability, more status information, and Diagnostic information for better maintainability.

DVP15MC11T can control multi-axis through the Motion interface, support single-axis motion commands such as position, speed, torque, origin return, etc., and support multi-axis commands such as electronic gear, electronic cam, rotary cutting, G code, etc.

DVP15MC11T can control 24 real axes (axis number range: 1-32).

The virtual axis and encoder axis can be built inside DVP15MC11T (the virtual axis and encoder axis number range: 1~32, which cannot be repeated with the real axis number).

Equipped with a 1GHz high-speed floating-point arithmetic processor, supports 64-bit floating point number (LREAL) and can be competent for a variety of complex motion control tasks.

Built in two incremental encoder interfaces and an SSI absolute encoder interface.

Built-in one RS-232, one RS-485, and two Ethernet interfaces.

built-in CAN interface, CAN do CANopen master station or slave station.

3.2 Control Plan

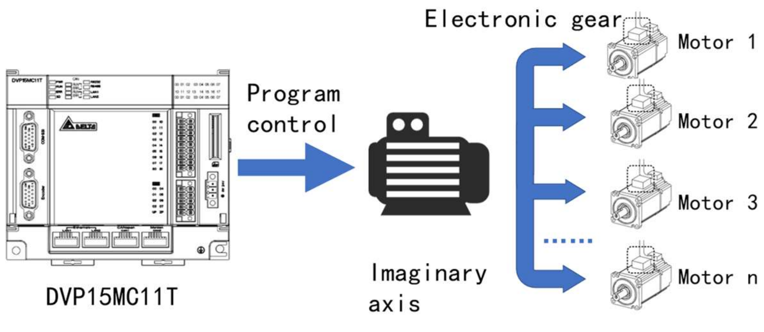

Figure 2. Schematic diagram of the control scheme

The virtual axis is an axis that does not exist in reality. It can convert the complex mechanical transmission relationship into a logical relationship in the program, which can simplify the

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mechanical structure and improve the accuracy and corresponding speed. Especially when there is a linkage or coordination relationship between multiple axes, the virtual axis can be set as a core controller or reference axis, an electronic gear relationship can be established with other coordinated axes, and finally, the linkage or coordinated action can be realized[4][5].

For the convenience of control, we have added two external input devices: a touch screen and an electronic handwheel.

3.3 Control Plan

The PLC connects the required servo drive and motor through the Motion port. The drives are connected in a "hand-in-hand" manner, and a 120-ohm terminal resistor is connected to the CN6 interface of the last motor. This is the premise for subsequent control. Add the corresponding axis to the internal Motion network configuration, so that all drives and motors can be connected to the communication channel.

Connect the touch screen and PLC through the RS485 interface that comes with the PLC to realize touch operation.

For the electronic handwheel, it is necessary to add an "encoder axis" to the Motion network configuration in the PLC and connect the electronic handwheel to the PLC through the Encoder port that comes with the PLC. This is the premise of electronic handwheel control.

4. Software Design of Control System

4.1 Synchronization Control Program

Enable the required axis using the MC_Power command. The imaginary axis does not need to be enabled. This can also verify that the imaginary axis is an axis that does not exist in reality.

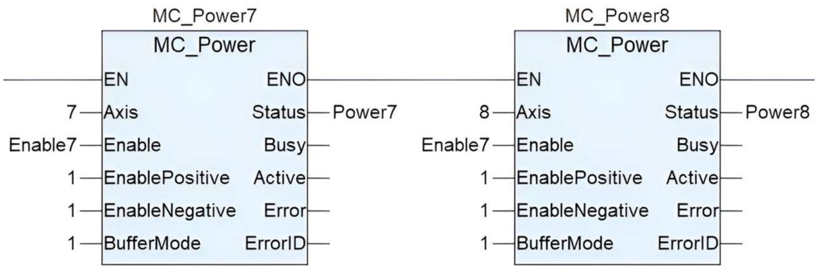

Figure 3. Two axes enable

Establish an electronic gear relationship between the motor to be controlled and the encoder shaft. As shown in Figure 4, The axis number of the imaginary axis we created in the Motion network configuration is"18", we specify it as the main axis, and we specify the 7th and 8th axes as slaves.

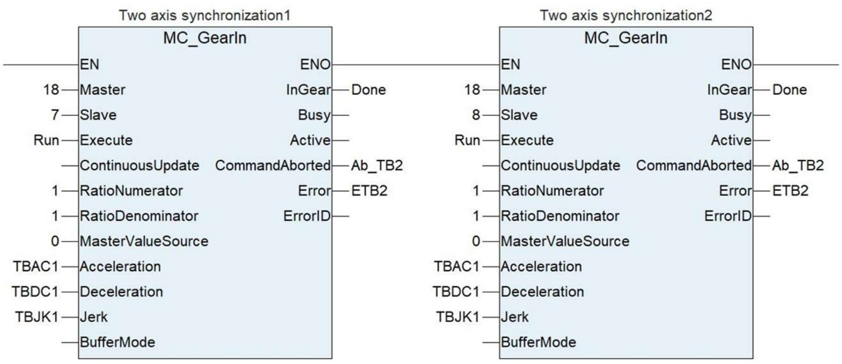

Figure 4. Electronic gear coupling

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When we press the "Run" button, the virtual axis (axis 18) establishes an electronic gear relationship with axes 7 and 8 with a gear ratio of 1:1. Subsequently, we indirectly synchronize control 7th and 8th axis by controlling the virtual axis to realize the pitch function of the lifting platform.

The virtual axis control command is the same as the physical axis control command, only the axis number is different. The commands include jog command: DMC_Jog, relative positioning command: MC_Move Relative, and absolute positioning command: MC_Move Absolute.

When the No. 18 axis performs jog, relative positioning, and absolute positioning, the 7th and 8th axis will move synchronously. During the movement, the measured position error of the two axes will not exceed 0.05mm, and the position error will not exceed 0.001mm after the movement. which meets our project requirements.

There will be a problem with the actual project. The actual position of the virtual axis does not have a memory function. After the PLC is powered on again, it will return to zero. At this time, the absolute positioning of the synchronous motion will be wrong, Because the actual position of the 7th and 8th axes and the current position of the 18th virtual axis are not synchronized. At this time, we need to use the MC_Home command to transfer the actual position of the 7th and 8th axes to the current position of the 18th axis.

4.2 Electronic Handwheel Synchronous Control Program

To enable the required axis, the MC_Power command is used. At this time, the virtual axis is not been used. The "encoder axis" corresponds to the electronic handwheel, and the encoder axis does not need to be enabled too.

Establish an electronic gear relationship between the motor to be controlled and the encoder axis, as shown in Figure 5, the axis number of the encoder axis we created in the Motion network configuration is "17", we specify it as the main axis, we specify the 7th and 8th axes as slaves.

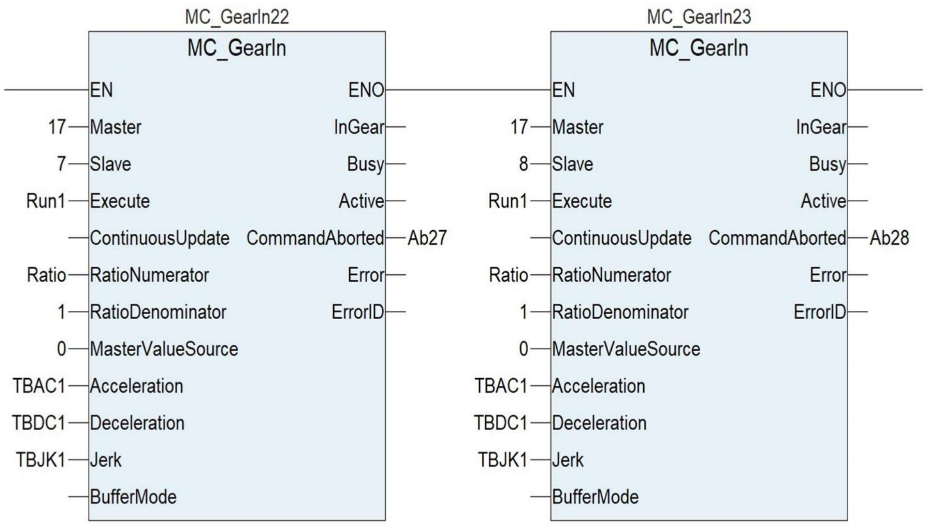

Figure 5. Handwheel 2-axis synchronization

When we press the "Run1 " button, the virtual axis (axis 17) establishes an electronic gear relationship with axes 7 and 8 whose gear ratio is "Ratio". The crank handle of the handwheel is used to indirectly synchronously control the 7th and 8th axes to realize the pitch function of the lifting platform.

5. Test

Test object: the 7th and 8th axes for synchronous motion.

Test method: To exclude other objective factors, in the closed-loop control mode, we usually raise the motor position from position 1 (pos1=1mm) to position 2 (pos2=2mm). The position of each motor is calibrated horizontally to ensure that the two motors are at the same height, and the position error in the result is expressed as the difference between the current position of motor 7 and the current position of motor 8 at a certain moment;

Test data: as shown in Table 1 (the number of experiments is much more than 10 times, the data in the table below are arbitrarily selected).

Table 1. Synchronized Control Test Results

Numble	Position error during operation (mm)	Position error after running (mm)
1	0.01572	0.00019
2	0.00293	0.00020
3	0.01137	0.00019
4	0.00529	0.00024
5	0.01128	0.00020
6	0.00276	0.00039
7	0.01457	0.00083
8	0.00947	0.00017
9	0.01763	0.00041
10	0.01498	0.00095

Data analysis: No two motors can maintain the same height during synchronous motion. Undoubtedly, there must be some objective factors, such as the accuracy of the lead screw, the performance of the motor, the acceleration and deceleration of the control module, and so on.

6. Conclusion

Conclusion: After the actual test, the accuracy of the interferometer can reach the accuracy required for use, and even if some positional errors occur, as long as the mechanical structure meets the requirements, the positional errors between the two axes will not be superimposed, which is sufficient to meet the requirements. Use needs. Due to space limitations, this paper only gives a 2-axis synchronous design, but it can achieve 4-axis or more synchronous control.

However, the problem that needs to be solved urgently is the position control accuracy in the case of high-speed motion, because it is found in actual use that when the synchronous speed reaches a certain value, the position error between the two axes will exceed the allowable range of the mechanical structure.

The work being done is to further improve the stability of the two motors during operation. If it is successful, I believe it will have practical significance for more productive activities in reality, which can improve production efficiency while improving operating accuracy.

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