Automatic Text System Based on PLC for Walk-Through Metal Detector

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Abstract. In recent years, the safety situation around the world is very serious. Each country has higher quality requirements for walk-through metal detector, and the newly issued standards are stricter. It has required precise and detailed testing work. Therefore, an automatic test system was designed to meet the requirements. The system was an AC servo system based on PC+PLC, with the control core of PLC and three-dof motion platform composed of servo motor and linear module to perform slide components. The paper focused on the overall architecture, structure design, working process, hardware composition, PLC programming and software functions of the system. The system has no interference to the testing work of metal detector with good testing ability and high positioning accuracy. The system improves the accuracy of the testing, and provides a friendly man-machine interface, which greatly reduces the working intensity of testers.

1 Introduction
In recent years, the safety situation around the world is very serious. Each country has higher quality requirements for walk-through metal detector, and the newly issued standards[1] are stricter. It has required precise and detailed testing work, the technical indicators and test methods have been greatly adjusted. Only the automatic testing system can achieve the accuracy and repeatability which is difficult to be achieved by the traditional testers. The US standard NIJ is also equipped with the automatic testing system.

Therefore, an automatic test system is required to meet the requirements and replaced the traditional testers[2-7]. The tester only needs to operate the software to make the test object passing the metal detector with specified speed and position, and record the result automatically. An automatic test system is designed in this paper, which is using OMRON PLC as the core controller to control the servo motors with pulse mode. The system frees testers from repetitive manual operations and greatly improves positioning and motion accuracy.

2 Literature review
2.1 System design
The automatic testing system is mainly composed of PLC, PC, servo motors, linear module, limit switch, origin switch and industrial camera. Block Diagram of the system is shown in figure 1. The actuator of the system is a three-dof motion system, which is composed of a linear module and a servo motor in the three directions of X/Y/Z. All three linear modules are driven by gears and belts. The
The Z-axis is in the vertical direction. The X-axis is horizontal and parallel to the metal detector. The Y-axis is perpendicular to the metal detector and passes through the detection area of the metal detector. The main function of the system is to complete the whole testing process stipulated by the order standard and record the optical alarm signal of the metal detector automatically.

2.2 Structural design

The mechanical structure of the system is shown in figure 2, which is mainly composed of the following modules: base, Z-axis component, X-axis component, Y-axis component, fixture, control cabinet, camera, PC. The base is made of steel to ensure the stability of the system.

The difficulty design of this system is that, according to the national standard, there cannot be any metal materials except test objects within the range of 1.5m from the metal detector. Therefore, Y-axis components are required to be made from non-metallic materials, including belt, bearing, spring, fastener and all other parts.

2.3 Workflow

The workflow of the test system is shown in figure 3. Details are as follows:

1) After the system is energized, all ports are initialized, including the level state of limit switches and origin switches.

2) Open the software on PC, check the position of the motors automatically, and execute the reference point search program.

3) Set parameters and select standards on PC, enable automatic identification and alarm, test data storage and other functions.

4) Click to start test, the PC sends the parameters to the PLC, and then the PLC sends the pulse to the servo motors to control the triaxial movement accordingly. When the software prompts "whether to change a posture to continue the test", change the posture of the test object and complete the test.

5) When the software prompts "whether to save the test data", click "yes" to save the test data into the database file, and task completes.

2.4 Hardware composing

This system adopts OMRON SYSMAC CP series[8-9] PLC controller as the control core, and Schneider Lexium 23D series servo driver +BCH series servo motor[10]. The servo system selects the position control mode and converts the pulse signal and direction signal into angular displacement and rotation direction, which drives the servo motor to move to the specified position at the specified speed. The I/O distribution of PLC in the system is shown in figure 4.
2.5 Programming of PLC

PLC development software “CX-programmer” provides flexible programming style (trapezoid diagram, function block diagram, statement table) and lots of instruction set, which can complete complex function easily and quickly. According to the workflow of the system, the program is divided into two parts: initialization program and motion control program. Each program was written separately, which was simple structure, clear thinking, easy to debug and modify.

2.5.1 Initialization program Set the initial position of each axis, Initial state of limit switch and origin switch in the initialization program. Each time the autorun is started, load the configuration, set motors enable, complete the current speed identification, position identification and direction identification of the motion axis.

2.5.2 Motion control program Reference point search program: Reference point search is realized through the limit switch and the servo motor’s encoder. After the software initialization is completed, it will run automatically.

Motion control program: In the autorun mode, the three axes start simultaneously, the speed of X/Z axis is fixed value, and the speed of Y axis is determined by the instruction sent by PC. The displacement of the three axes is also determined by the instruction sent by PC. The data is written into the register and sent to the servo driver in the form of pulse frequency + direction signal and drive the servo motor to the specific stroke. At the same time, there is a stop motion program, press the stop button in the software, the three axes stop immediately. The trapezoid diagram is shown in figure 5.

Figure 3. Workflow of the system

Figure 4. The I/O distribution of PLC

Figure 5. Trapezoid diagram of motion control program
PC communication program: Since the testing work of the system has lots of repetitive motions, after the completion of a single test (the jig of the Y-axis component carries the test object through the metal detector and returns to the origin), the PLC program needs to send the motor state, origin state and pulse output completion state of the three axes to PC for the judgment basis of the next instruction.

2.6 Software functions
PC uses serial port (HOST LINK communication protocol) to communicate with PLC, and USB cable to connect with camera. The interface of PC software is shown in figure 6. Parameters that can be set include: position, speed, mode, test standard, test object, etc. In manual mode, posture, scanning interval, running times, position compensation can also be set.

![Figure 6. The interface of PC software](image)

3 Results
According to the structure and frame of the system, complete the installation of the whole machine and the connection of cable. After several tests, when the system passes through the metal detector without load, the security gate does not have an alarm, which proves that the system has no interference in the testing of metal detector and can meet the basic conditions of the test. The system can make precise point movement in the X/Y/Z directions, can carry the test object through the metal detector according to specific position, speed and posture. The system can automatically record the alarm lamp of the metal detector through the camera, and generate the test record form. The performance index of the system is shown in table 1.

| direction | positioning accuracy(mm) | stroke (mm) | Speed(m/s) |
|-----------|--------------------------|-------------|------------|
| X         | 0.2                      | 0-800       | 0.5        |
| Y         | 0.5                      | 0-2700      | 0.2        |
| Z         | 0.2                      | 0-2000      | 0.5        |

After the test, the system can generate the test form in excel format by clicking "export" button in the software. The test form records the test object’s name, posture, speed and position in the test process. The form contents are the alarm number of the test process, 0 when no alarms are made, and empty when no tests are made, as shown in figure 7.
4 Conclusions
This paper adopts mainstream industrial control products for system integration. Based on PLC and servo control module, an automatic test system for walk-through metal detector is constructed. The actual test proves, the system has good testing ability and positioning accuracy, which improves the accuracy of testing and greatly reduces the working intensity of testers. This paper has carried out a beneficial exploration in the field of metal detector’s testing, which has good practical application. The high efficiency, stability and security of the system are guaranteed, and a good human-computer interaction interface is provided, which has been highly praised by the industry personnel.

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| Position | Posture | GB-T2 | GB-T4-1 | GB-T4-2 | GB-T6-1 |
|----------|---------|-------|---------|---------|---------|
| 1-190W   | Transverse | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Vertical   | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Longitudinal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2-170W   | Transverse | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Vertical   | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Longitudinal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3-145L   | Transverse | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Vertical   | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Longitudinal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4-145W   | Transverse | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Vertical   | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Longitudinal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5-125W   | Transverse | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Vertical   | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Longitudinal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6-100L   | Transverse | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Vertical   | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Longitudinal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7-100R   | Transverse | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Vertical   | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Longitudinal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8-75M    | Transverse | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Vertical   | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Longitudinal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9-40L    | Transverse | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Vertical   | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Longitudinal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10-40R   | Transverse | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Vertical   | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Longitudinal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11-10L   | Transverse | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Vertical   | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Longitudinal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12-10R   | Transverse | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Vertical   | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Longitudinal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Figure 7.** Test form of the system
manipulator [J]. *Science & Technology Information*, 2008(18):30-31.

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