Journal of Physics: Conference Series

PAPER • OPEN ACCESS

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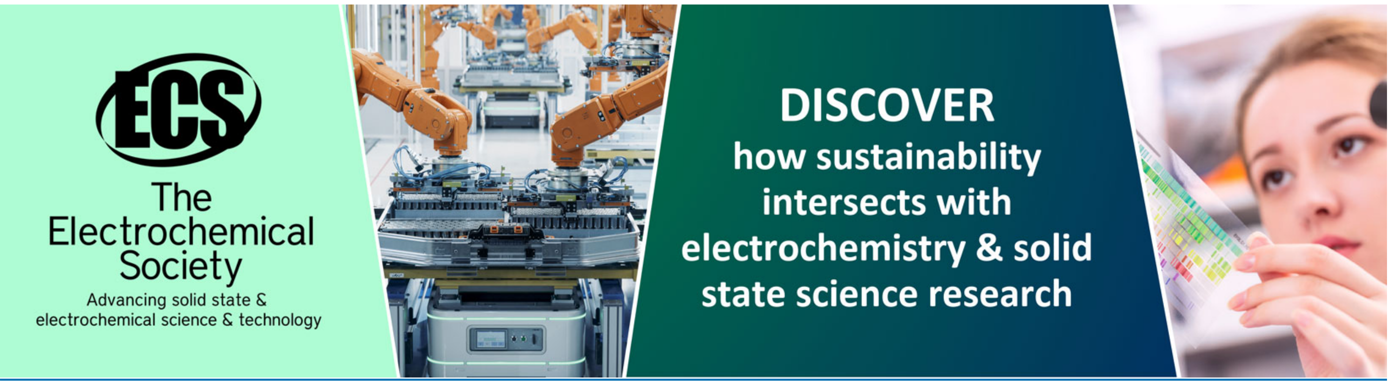
To cite this article: Weiwen Tian *et al* 2020 *J. Phys.: Conf. Ser.* **1570** 012022



Design of Control System for Pressure Vessel Inspection Robot Based on PLC

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Abstract. In order to improve the detection efficiency and quality of pressure vessels, a pressure vessel inspection robot control system based on programmable logic controller PLC is designed. First, the basic structure of the inspection robot is briefly introduced, and then the software and hardware of the control system of the inspection robot are designed in detail. Hardware design includes overall hardware design, hardware selection, hardware electrical circuit design, actual layout of hardware, etc. Software design includes software design process and program design, among which Mitsubishi FX5U series PLC and FX5-40SSC-S motion control module are the core of the control system. Finally, it is experimentally verified that the control system can control the detection robot well and has high engineering value.

1. Introduction

The pressure container is a sealed container containing liquid and gas, which can bear a certain pressure. It has a very important position and role in many fields such as industry, civil and military. The liquid or gas in the pressure vessel makes the pressure vessel work under high pressure, high temperature, flammable, explosive, and highly toxic and corrosive environments for a long time [1]. Once a leak explodes, it is often accompanied by disasters such as fire and environmental pollution. Not only will it cause economic losses, but it will also seriously threaten people's lives. This needs to ensure the tightness of the pressure vessel, especially the weldment. At present, most of the traditional pressure vessel testing is manual testing, and this testing method is not safe for testing personnel and the testing efficiency is not high. Therefore, new detection methods are needed to improve detection quality and efficiency.

This paper designs a PLC-based pressure vessel inspection robot control system [2]. The designed control system can control the detection robot to carry the ultrasonic tracker to automatically track and control the welds in the pressure vessel. And it uses PLC and motion control modules as controllers, which improves the accuracy and stability of tracking, and can effectively replace manual detection. Therefore, it is of great practical significance to study the detection robot control system.

2. Design of the inspection robot's body structure

The pressure vessel tanks tested in this project are large spherical tanks, and the tanks are mainly made of ferromagnetic materials [3]. Therefore, the robot uses a track-type magnetic adsorption structure, and the permanent magnet is installed on the track. The design of the robot adopts a modular idea, in which the vision module based on the visual sensor completes the collection of the weld information so that the robot can track the weld. It is installed in the front of the robot. The detection module based on the detector is used for Detecting defects in welds. Mounted on the tail of the robot. Tracks with permanent magnets are installed on both sides of the car body, which are driven by driving motors respectively, and the control module is located inside the car body [4,5]. As shown in Figure 1.

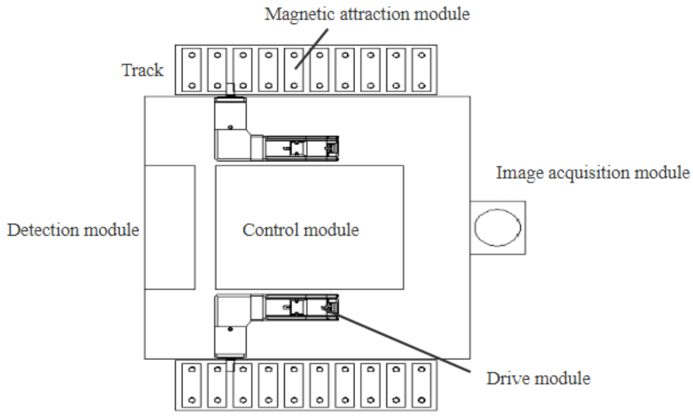

Figure 1. Structural diagram of detection robot body

3. Hardware design of inspection robot control system

3.1 Design of the overall scheme of the detection robot control system hardware

The overall architecture of the robot hardware design is divided into upper and lower layers [6], which are divided into upper computer and lower computer. The upper computer is a high-performance industrial computer that mainly completes image processing, data transmission, and status monitoring. The vision sensor and optical fiber transceiver constitute the vision. The system is wired to the host computer. The lower-level machine PLC receives the control instructions from the upper-level machine and directly controls the servo motor to complete the straight-line walking and steering of the robot to form a motion control system. The motion control system and vision system are installed on the robot body, the upper computer is outside the pressure vessel, and the two are connected by a proprietary cable. The control system hardware system diagram is shown below.

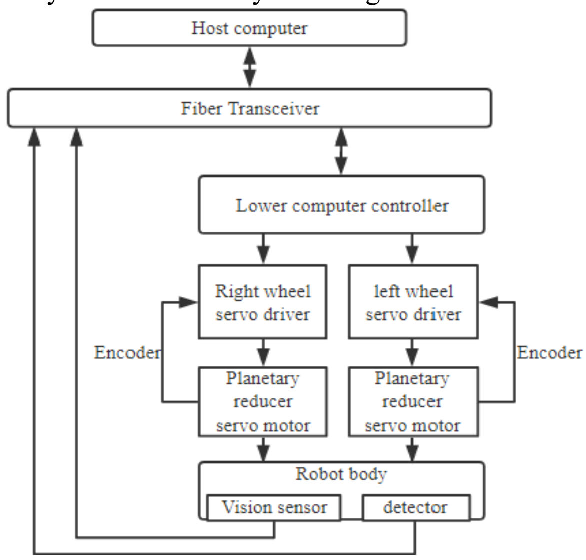

Figure 2. Control system hardware design system diagram

3.2 Robot control system hardware selection

Robot control system hardware mainly includes: PLC and motion control module, drive motor module, vision sensor, fiber optic transceiver, etc. Among them, the PLC uses Mitsubishi's FX5U-32MT programmable controller. This PLC has the advantages of fast calculation speed. The motion control module is a four-axis motion controller module FX5-40SSC-S that is matched with the PLC. This module has multiple functions. Smart module. The servo motor uses Mitsubishi series low-inertia small-capacity HF-KN43 (B) J-S100. The matching driver is Mitsubishi servo driver MR-JE-40B. The planetary reducer is a BIPTASS WHTF series planetary reducer. As shown in Figure 3 and 4, it is a PLC and a motion control module. Other hardware has physical map in the hardware layout.

Figure 3. PLC

Figure 4. FX5-40SSC-S motion controller module

3.3 Electrical circuit design

After the robot control system hardware is selected, the electrical circuit is designed according to the hardware composition of the robot. The design of electrical circuits mainly includes power supply circuit and brake circuit design.

3.3.1 Power supply circuit

Power supply is necessary for every electrical circuit, because the design of the power circuit is the basis for the operation of the entire electrical circuit. The power required by the robot is 220V AC power and 24V DC power, of which 24V is converted from 220V by a 24V switching power supply. 220V is mainly used for PLC and servo driver, in which servo driver and servo motor are energized through the power connector port. As shown in Figure 5, it is the wiring diagram of the power supply electrical circuit.

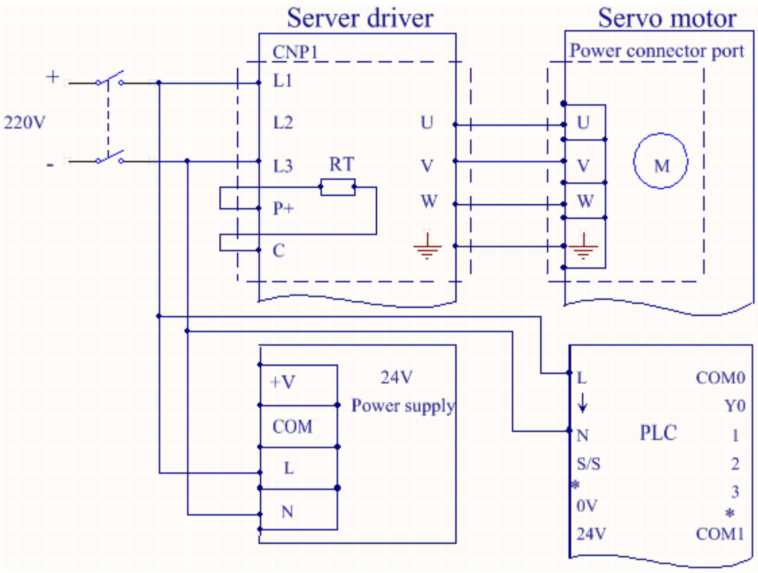

Figure 5. Power electrical wiring diagram

3.3.2 Brake electrical circuit design

Below we focus on the brake circuit, how to design the electrical circuit of the electromagnetic brake port of the servo motor.

As shown in Figure 6, it is the electrical circuit diagram of the relay, servo driver and servo motor. The servo drive CN3 port has a total of 4 pins. This article only uses the MBR and DOCOM ports. When the sink type input and output interface is used, the DOCOM end is connected to the negative 24V external power supply. When the source type input and output interface is used, the DOCOM end is connected to the 24V external power positive electrode. The relay in the robot is composed of 4 identical parts, that is, the line in the dotted frame in the figure. The relay plays the role of safety protection and transfer switch. The 24V switching power supply provides power to the electromagnetic brake ports of the servo driver and servo motor. Only when the pin MBR of the input and output signal connector (CN3) is connected to the pin DOCOM, the relay coil is energized and the normally open contact is closed, so that the electromagnetic brake is energized and the servo motor runs normally. When CN3 is powered off, the normally open contact is opened, the electromagnetic brake is de-energized, and braking starts.

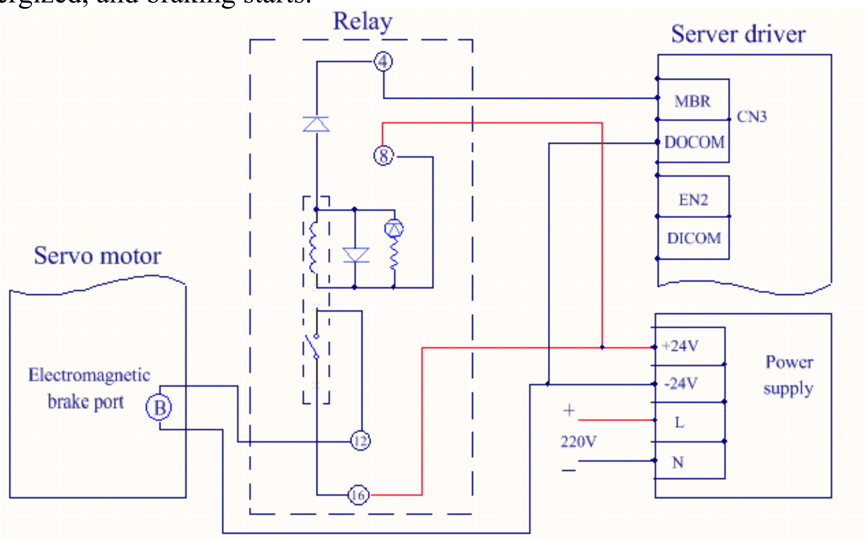

Figure 6. Brake electrical wiring diagram

3.3.3 The actual layout of the hardware

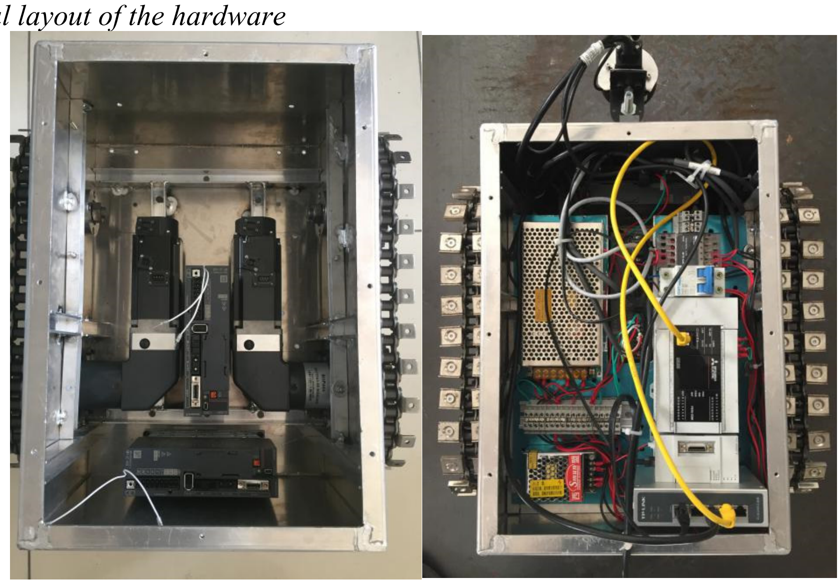

Figure 7. Hardware layout diagram

Based on the above, the actual circuit design and detection robot's actual shape and space, and the actual layout of the hardware and circuits are carried out.As shown in the figure above, it is the hardware layout of the robot control system. The upper and lower layers are separated by aluminum plates. The left picture shows the hardware installation layout of the lower layer. Two servo motors, servo drives and planetary reduction wheels corresponding to the servo motors are installed on the lower level. The upper layer is mainly installed with a PLC controller and a motion controller module, a 24V switching power supply, a 12V switching power supply, and a fiber optic transceiver. At the same time, a vision sensor is installed on the front end of the detection robot.

4. Software Design of Inspection Robot Control System

The hardware system is the basis of the robot. On this basis, the software system can be used to give the idea to the hardware system. Therefore, the software design should be followed. The software design of the pressure vessel detection robot control system should follow the software design process. The software design process mainly includes functional requirements Analysis, program flow analysis, program writing, Program conversion, Experimental debugging, etc. The flow is shown in Figure 8.

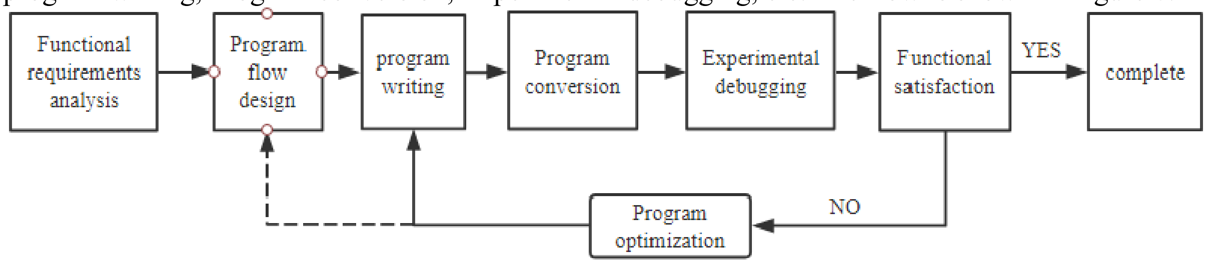

Figure 8. Software design process

4.1 Design of Weld Tracking Control Program

Robot seam tracking is a process that automatically executes motion control commands sent by the host computer software. First, the host computer processes the weld image and obtains the center line of the weld. Then, the relative position between the robot and the weld is calculated. The speed of the left and right wheels of the robot is adjusted by the control algorithm, so that the robot continuously moves left and right, reducing the relative position of the weld and the robot, and tracking the weld. Figure 9 is a flowchart of the welding seam tracking control program.

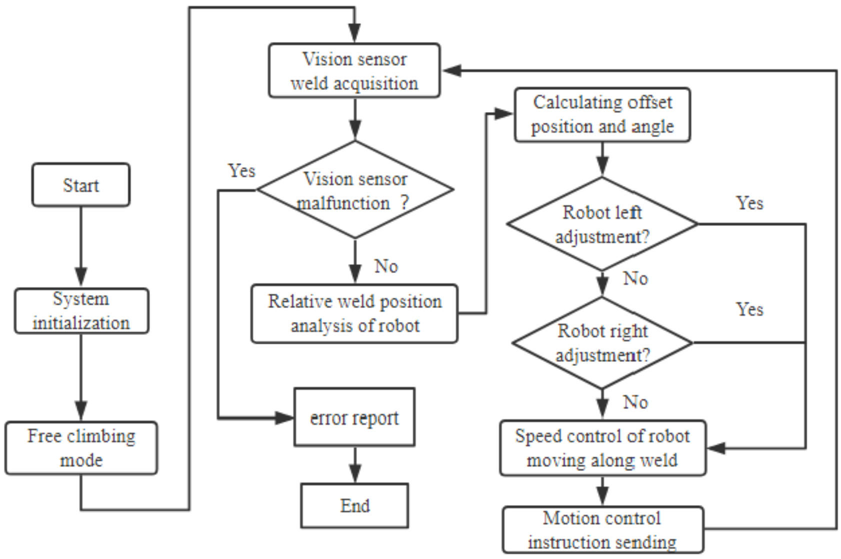

Figure 9.Weld tracking control program flow

5. experiment analysis

After completing the software and hardware design of the inspection robot, in order to verify whether the robot can complete the inspection operation, welding seam tracking experiments and bevel motion performance experiments were performed on it. Experiments of various tilting angle motions are shown in Fig. 10. In the tilted state, we performed speed tests and passed weld tests. Experiments have proved that the prototype can guarantee stable speed under various inclination angles, and there is no severe jitter and slip when passing through the weld. There is no overturning or other accidents in the experiment. The reliability and stability of the inclined plane motion can be obtained through experiments.

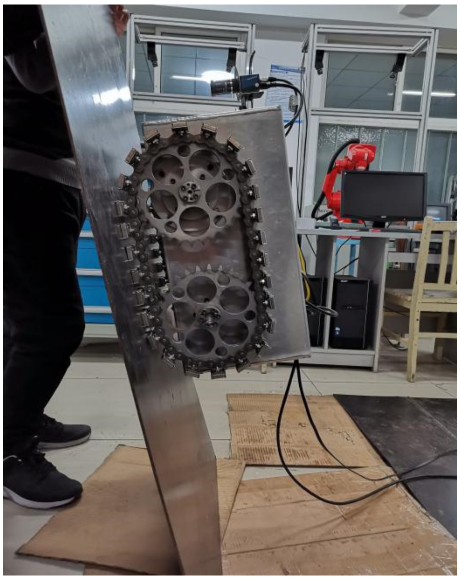

Figure 10. Bevel motion experiment

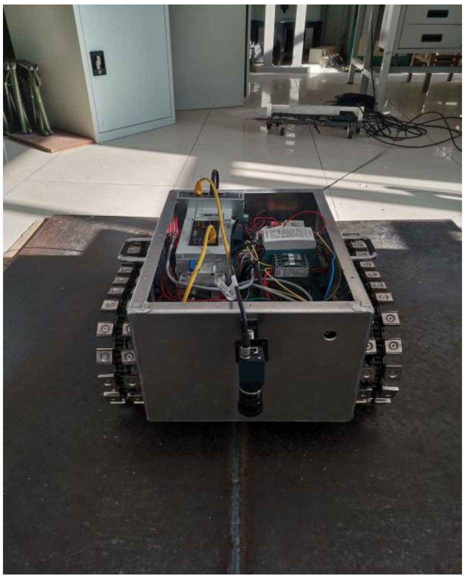

Figure 11. Software design process

As shown in Figure 11, it is an experimental diagram of welding seam tracking. From the experimental results, it can be concluded that the robot designed in this paper can well track the welding seam straight line and can achieve ideal results. However, the speed of the robot during the experiment has a certain effect on the welding seam tracking. Because the permanent magnets and steel plates on the crawler are constantly attracting and leaving when the robot is running, this will inevitably cause the robot's prototype to shake. If the running speed is faster, the degree of shake of the prototype will be greater, which will cause The tracking error of the robot is relatively large. Experiments show that when the robot prototype moves at the working speed, the tracking error is within an acceptable range.

Table 1 and Table 2 are the statistics of the deviation between the robot and the weld when the robot moves the same distance at different running speeds. It can be seen that when the speed is 5 cm / s, the tracking deviation is smaller. Therefore, the tracking effect is better at lower speeds.

Table 1. When the robot speed is 5cm / s, the experimental data of the welding seam is tracked

Moving distance	0cm	5cm	10cm	15cm	20cm
Deviation	50mm	42mm	30mm	15mm	5mm

Table 2. When the robot speed is 6cm / s, the experimental data of the welding seam is tracked

Moving distance	0cm	5cm	10cm	15cm	20cm
Deviation	50mm	46mm	35mm	20mm	11mm

6. Conclusion

This paper designs a control system for testing robots for testing pressure vessels. This control system uses Mitsubishi's FX5U-32MT programmable controller and its supporting four-axis motion controller module FX5-40SSC-S as the control core, and is selected in combination with other hardware, the hardware design of the inspection robot control system is completed, and the software design is done on this basis. Finally, the robot was experimentally verified, and it was found through experiments that the detection robot can complete the detection of pressure vessels, which has certain reliability and practicability.

Acknowledgments

This work was supported by funding from the Ordoste Equipment Inspection Institute and technical support from teachers at the Robotics Laboratory of Inner Mongolia University of Technology. Thanks for that.

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