Design of laser welding workstation control system based on industrial robot

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Abstract. In order to realize the automation of laser welding industry, a control system of laser welding workstation based on PLC and industrial robot is designed. The control system takes ABB industrial robot and S7-300 PLC as the control core, adopts PROFIBUS bus communication, carries out the hardware selection, construction and program design of workstation control system. Production practice shows that the system workstation can automatically complete laser welding and other production tasks, the overall operation is good, the working speed is stable, the working speed is fast, and it has broad application prospects.

1. Introduction

With the development of robot and digital manufacturing technology, intelligent technology represented by artificial intelligence and intelligent equipment represented by robot are increasingly widely used. The labor-intensive industrial model based on processing and manufacturing is gradually eliminated, which makes the configuration mode of global technical elements and market elements revolutionary change [1, 2].

Laser welding robot is an industrial robot for laser welding automatic operation. Through high-precision industrial robot, more flexible laser processing is realized. The tool held at the end is laser processing head. It has the minimum heat input and generates a minimum heat affected zone, which can significantly improve the quality of welding products and reduce the time of follow-up work [3-5].

Laser welding has been a mature non-contact welding method for many years. High energy density makes high-speed machining and low heat input possible. Compared with robotic arc welding, robot laser welding requires higher seam tracking accuracy. The basic performance requirements are as follows:

1) High precision trajectory (≤ 0.1 mm);
2) Holding weight (30 ~ 50 kg) to carry laser processing head;
3) It can communicate with laser at high speed;
4) The manipulator has good rigidity and wide working range;
5) It has good vibration suppression and control correction functions.

In recent years, industrial robot technology has developed rapidly. As a high-end intelligent equipment which can imitate manual operation, programmable and automatic control of laser welding robot, industrial robot has high automation and flexibility [6, 7]. In this paper, the laser welding automation and integrated control as the goal, according to the laser welding function and workflow
analysis, Siemens S7-300 PLC as the control core, designed the laser welding workstation control system based on industrial robot, realized the machine replacement and automation.

2. System structure and working principle

Laser welding robot workstation is composed of industrial robot system, control system and laser system, as shown in Figure 1. According to the degree of freedom, space and load, the industrial robot selects ABB's irb2600 robot. Its working range is 1.65m and the load is 15kg. It has the characteristics of compact body, large working range, flexible installation, and fast operation speed. The industrial robot system is installed on the gantry, and a servo controlled sliding platform can move in a straight line under the robot. The industrial robot workstation and laser end effector are shown in Fig. 2. When the industrial robot works, the Profibus bus control between the robot controller, laser controller and PLC is used to complete the laser welding control of the workpiece placed on the platform.

According to the working space and production process of the enterprise, the working principle of the laser welding robot workstation is: when working, the welding tool is placed on the mobile platform, and the workpiece is fixed, the laser control is started, and the robot trajectory program is written. In the automatic mode, the robot end actuator reaches the predetermined position, and then approaches the workpiece to cooperate with the servo sliding mechanism for laser welding. After processing, the welding joint is far away from the workpiece, and finally the industrial robot reaches the safe position.

![Figure 1. System components.](image1)

![Figure 2. System layout and laser diagram.](image2)
3. Hardware design of control system

The control system hardware of laser welding workstation mainly includes robot controller, laser system, PLC, touch screen, servo system, solenoid valve and sensor, etc. The electrical hardware design structure diagram is shown in Fig. 3, in which the cable of laser adopts EW φ 36 hose, as shown in Fig. 4. In the whole control system, PLC and industrial robot controller irc5 are used as the core of the control system. PROFIBUS bus communication is used to receive and collect external signals to realize the laser welding of industrial robot and control the start and stop of welding platform motor.

The hardware selection of control system is as follows:

1. Industrial robot controller: the robot controller adopts irc5, and the controller is equipped with DeviceNet Bus interface to facilitate PLC communication. At the same time, its motion control technology, true move and quick move are the important guarantee of robot performance indexes such as precision, speed, cycle time, programmability and synchronization with external devices.

2. PLC controller: Siemens PLC programmable controller S7-300 series 6es7314, its CPU 314c-2dp, compact CPU with integrated digital and analog input / output and PROFIBUS DP master / slave interface is used to connect distributed I / O. Due to the huge control system of the workstation, PLC communicates with industrial robot through PROFIBUS DP communication interface. At the same time, through the integration and expansion of I / O module, the signal control and information processing of sensors, solenoid valves and servo drives are carried out.

3. Laser: the laser adopts the Ruike fiber laser. Compared with the traditional laser, the fiber laser can increase the pump light conversion efficiency per watt by more than 10 times. The automatic design with low energy consumption is suitable for laboratory or outdoor operation. It can be placed independently, can be used at any time, and can be directly embedded in the user's device. Three phase 380V ± 10% and 50 / 60Hz alternating current is required for 1000W CW fiber laser.

4. Bus module: Siemens PROFIBUS module is used in the control, which is used to connect the module interface on the PLC host and the robot bus as the data exchange interface between the PLC host and the slave station on the bus.

5. HMI human machine interface: Siemens tp700 comfort touch screen is adopted, which can be connected with Siemens S7-300 through bus to realize the setting and monitoring function of industrial robot process parameters.

6. Servo system: the servo motor of Yaskawa company of Japan is used to realize the control of platform movement through PLC.
4. Program design and operation of control system

4.1. Programming of control system

The program design of laser welding workstation control system mainly includes PLC program design and robot program design. According to the working principle of the laser welding workstation, according to the robot end laser start preparation, welding workpiece clamping, platform moving, robot approaching the workpiece for laser welding, after welding, put it to the safe position and start the cycle again. The whole system program design includes system initialization, HMI process parameter setting, manual operation, automatic operation, signal monitoring system, etc. the program flow chart is shown in Figure 5. The whole program is programmed according to the modularization to ensure the stability of the system, and interlock and other security protection are needed.

(1) System initialization: when the system is started up, the control system of laser welding workstation will run to the initialization state according to a certain safety sequence, so that the workstation will return to the original state, and the workstation is ready to start operation.

(2) HMI process parameter setting: according to the welding object and process requirements, the corresponding parameters are set in HMI human-machine interface to meet the stability and effectiveness of equipment production;

(3) Manual operation: during the joint debugging of the whole machine, the laser welding workstation can run and debug independently according to the function module, the laser welding and workpiece clamping action of the test workstation can be realized, the laser controller can be opened, the servo control of the workpiece platform and the start-up and stop control of the robot can be made for the joint automatic operation of the whole machine.

(4) Automatic operation: once the parameters are set, it will enter the automatic operation state under normal conditions, and automatically complete the laser welding work of the workpiece to realize the automation of production. It can be started by the start of button or touch screen, and stop after receiving the stop command.

(5) Signal monitoring system: through signal monitoring, we can monitor the operation of the system, the functional status of laser welding, the running speed of robot and motor, etc., so that the whole production process is under control.

The industrial robot control program is designed by rapid programming of ABB industrial robot. The whole system design includes main program design and subprogram design. The subprogram design includes initialization, workpiece platform setting, interrupt program, laser welding execution program and other functional modules. The main program design is to set the robot safety position point, judge the logical sequence, and adjust the subprogram The main program of robot laser welding is as follows:

```
MODULE MainModule
Proc main () / / main program
S_ Inizio; / / initialization
R_ Parametri; / / call the workpiece platform settings
S_ Interrupt; / / interrupt program
Movej CASA, S200, Z1, tool1; / / robot safety location
IF (DI10_ 1 = 0) then / / signal to judge whether the workpiece is ready to continue
GOTO lbl_ 1. / / if the workpiece is not fixed properly, the program will jump to IBI U 1
IF DI10_ I = 1 then / / if the workpiece is fixed
TPErase;
S_ Pallet_ 1. / / the procedure for laser welding will be performed
ENDIF
ENDDPROC
```
4.2. Operation of workstation control system

The laser and workstation of laser welding workstation are shown in Fig. 5 and Fig. 6. The laser head is used as a tool to set laser parameters, plan welding track of industrial robot, set fence and emergency stop button for safety protection. When the system is running automatically, the industrial robot can quickly complete the laser welding work, the working efficiency is fast, the working state is stable, and the welding quality reaches the standard level.

![Figure 5. Laser welding](image1)

![Figure 6. Laser welding workstation](image2)

5. Conclusion

This system takes ABB industrial robot irc5 and Siemens S7-300 PLC as the control core, adopts PROFIBUS bus communication, combines touch screen technology and servo drive technology to design the control system of laser welding industrial robot. The system workstation can automatically complete the functions of workpiece clamping preparation, robot laser welding and grinding. The practical application shows that the whole system runs well, the working speed is stable and the working speed is fast. It has broad application prospects.

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