Design of welding control system based on Siemens PLC

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Abstract. In order to accelerate the rapid development of the automobile manufacturing industry and improve the competitiveness, a welding control system of automobile dashboard bracket based on Siemens PLC is designed. The welding control unit of automobile dashboard bracket takes Siemens PLC as the control core, to realize real-time control with welding fixtures, robots, the sliding door with monitoring, the shutter door and other parts through a touch screen. The entire design system realizes welding control of automobile dashboard bracket, meeting production process requirements, effectively reducing costs and improving production efficiency.

1. Introduction

With the rapid development of automobile manufacturing industry, welding technology has been widely used because of its low energy consumption, high precision and fast welding speed. From the history of the development of the auto industry, the automobile welding production line has gone through three stages: the manual welding line in the 1950s and 1960s, the automated rigid welding line in the 1970s, and the flexible welding line in the late 1980s[1-2]. At present, the welding production line of automobiles can greatly improve the automation degree and production efficiency by using welding robots and other equipment. However, the increased degree of automation will inevitably lead to an increase in the complexity of the equipment of the welding production line, more control processes, and the control difficulty will be greatly increased. In order to increase the competitiveness of domestic auto companies in the world, we should independently develop and design automated, flexible welding units and welding production lines that meet the needs of the domestic automotive industry.

In order to solve the problems above, this paper designs a welding control system for automobile instrument panel bracket based on Siemens PLC. This equipment can effectively accelerate the production of automotive parts and components, and it can improve production efficiency and reduce production costs.

2. Hardware configuration

The hardware of the welding control system mainly includes Siemens PLC, input and output modules, sensors, servo motors and its controllers, frequency converters and the touch screen.

The welding system of the automobile dashboard uses the S7-300 series produced by the Siemens Company as the controller to form the Profibus-DP distributed bus control system[3]. The controller uses Siemens CPU 317F-2 PN/DP as the main station, and the slave station uses Siemens ET200M interface module for DP bus communication to realize remote IO control.
The Siemens KTP1000PN Basic touch screen is selected as the human-machine interface in the welding unit operating system, and Industrial Ethernet is used as the transmission medium to realize real-time communication with the CPU. The CPU controls the device to complete the specified operation by receiving the input signals. On the one hand, the touch screen collects the operation signal from the device, on the other hand, it returns the running state of the equipment to the touch screen to realize the real-time monitoring of the production process. In the control system, the PLC collects external signals as input and performs the output units such as solenoid valves and relays. The field bus is connected with the servo controller to control the servo motor on the spot. In order to meet the design requirements of the welding control system, a schematic diagram of the control system structure is designed, as shown in figure 1.

Figure 1: Schematic diagram of the control system

As the core of the welding control system, PLC should first determine its type. The key to choosing the type is to define the storage capacity of the welding control system and the number of I/O points required by the control system. In the early stage of design, I/O points are mainly calculated by the estimation method due to the unknown program. Firstly, I/O points in the welding control system should be counted, including the digital input/output and the analog input/output. Considering the possible omission of I/O points, it is necessary to increase 10% on the basis of statistics. Meanwhile, taking into account the later transformation of welding units, it is necessary to increase 10%-30% on the basis of the total I/O points obtained by statistics, which will also facilitate the maintenance and upgrading of equipment and increase its expandability in the future. If some endpoints fail, they can be replaced by reserved points. The number of I/O points can reflect the system requirements of PLC to a certain extent, so on the basis of I/O point estimation, after leaving enough margin, the demand for PLC memory capacity can be calculated. The empirical formula for calculating memory capacity is as follows:

\[
\text{Storage(KB)} = \frac{(1-1.25)*(DI*10+DO*8+AI/AO*100+CP*300)}{1024}
\]

(1)

Among them: DI - The total number of digital input points;
DO - Total number of digital output points;
AI/AO - The total number of analog I/O channels;
CP - The total number of communication interfaces.

According to the above formula (1), the memory capacity of the welding unit is 7.75KB.

Through the calculation above, considering the communication and upgrading requirements of the system, Siemens S7-300 series module is selected as the PLC module of the welding unit, and CPU 317-2PN/DP is selected as the PLC module of the system. The 317 series module has high performance, high operation speed and short scanning period, which can greatly improve the production efficiency and accuracy of the welding unit.
To meet the requirements of stability and reliability of the welding control system, when selecting servo controllers, the touch screen, relays, etc., the products that are reasonably priced and convenient to use should be selected as much as possible to satisfy the production requirements and functions.

3. Design of the welding unit

The main function of the welding unit is to place the fixture and weld the parts positioned on the fixture to form a complete integrated vehicle dashboard bracket. The welding unit is mainly composed of a protective shell, safety light curtain, rolling door, sliding door with monitoring, four-station turntable, three industrial robots, welding equipment, four fixtures and main control cabinet, etc. As shown in figure 2, the welding production line is mainly composed.

![Welding production line diagram](image)

Figure 2: Main components of the welding production line

Due to the high degree of automation in the welding production line, a workstation mainly completes its regular work, which requires the welding system to be safe and reliable, and to complete its specified actions[5]. In order to improve the production efficiency of the welding unit and reduce the loading time and waiting time of each component, the welding unit is divided into a placement area, a waiting area and a welding area.

According to the production process requirements of the welding unit, the space utilization rate of the welding unit and the space size of each part are fully considered, the position diagram of each part of the welding unit is designed as shown in figure 3. The protective enclosure is designed with a monitoring sliding door, a rolling door and a safety light curtain. The rolling door is located at the front of the welding unit when the welding unit is working, the rolling door cannot be opened, which can effectively separate the dangerous area from the outside. The safety light curtain will monitor the placing area between the clamping fixture and the shutter door passage when the shutter door is opened. Before the rolling door is closed, the safety light curtain will inspect the entire placing area to prevent the operator from being locked in the protective casing of the welding unit. The sliding door with monitoring is located at the end of the welding unit and can enter the welding area.

![Welding unit components diagram](image)

Figure 3: Location of the welding unit components
The welding control system of the instrument panel bracket designed in this paper has strong procedural characteristics, which means that there are many parts of the bracket. During welding, according to the process and welding efficiency, four fixtures are installed in the same welding unit, and the upper part - welding - lower part actions are completed in four steps. Since the welding robots are fixed on the chassis of the welding unit, the fixtures are installed on the four-station turntable and driven by the servo motor and gearbox. The procedure of the working turntable is as follows: The power of the turntable is provided by a servo motor installed under the turntable. The servo motor is decelerated by the gearbox to drive the four-station turntable. The turntable driving mechanism rotates the fixture for placing the parts by 90° to the waiting area after the operator starts the welding unit button, and rotates the fixtures containing the parts in the waiting area to the welding area for the welding operation. The workflow diagram of the turntable is shown in figure 4.

The working process of the welding unit is as follows: during the initial work of the welding workstation, it shall first check whether the shutter door is closed. If the shutter door is not closed, the operator should be alerted via the touch screen. When the shutter door is closed, it continues to detect the size of the air pressure, if the pressure is small, the system should adjust the pressure size in time; After the completion of the preparation, welding control system begins to work, cylinders and fixtures complete the clamping of the parts, transport the parts to the welding area, and detect whether the fixture reaches the specified position and the position of the robot. When both meet the conditions, the welding process can be entered, otherwise the system will prompt the alarm. Only by solving the alarm can we continue the next step. At this point, the car dashboard bracket is welded. The workflow of the welding unit is shown in figure 5.

Figure 4: Turntable workflow

Figure 5: Welding unit workflow chart
4. Design of human machine interface
The man-machine interface of the welding control system is mainly composed of the home screen interface, the main function interface, the diagnosis interface, the detection interface and the error alarm interface. As shown in figure 6, the main home interface includes the main function button, the diagnosis button, the alarm and history error button and the language selection button. Through the home screen interface, the corresponding sub-interface can be entered to further complete the operation of the device[6].

![Figure 6: Schematic diagram of the home screen interface](image)

The main function interface also integrates the manual operation button of the fixture, the robot function button and the functional operation button of the whole welding unit. This design can greatly facilitate the operation of operators. The manual operation button of fixture is touched, it enters the operation interface of the fixture cylinder, according to the design button of touch screen, the corresponding cylinder can be clamped or loosened; the robot function button is touched, it enters the robot operation interface, which can operate the robot's return point, self-detection and other functions; the functional operation button of the welding unit is touched, it can control the switch of the rolling door, the movement of the parts library up and down, and the switch of the welding gun.

The diagnostic function interface can diagnose whether the communication of each function module or the device works normally. If each function module works normally, the indicator light in front of the function is green, otherwise, it is red, and the fault needs to be checked.

The monitoring function interface is the interface for monitoring the work of each sensor, which can monitor the running status of each sensor in real time. In the production process, it can be intuitively seen from the touch screen whether each sensor has a signal, and then the working status of each station is known. If the sensor signal corresponding to the detection interface on the touch screen is blue, the station runs well, otherwise, it will be shown as red.

The erroralarm function interface can alert the operator when an error occurs in the component or the operator is wrong to operate. In the error alarm sub-interface, the historical error message of the welding unit can also be viewed. The designed error alarm interface mainly shows the errors and alarms in the welding unit, and is connected with the external red, green and orange signal lamp. When there is an error alarm, not only the operator can be prompted on the touch screen, but also the signal lamp can be flashed. If the error cannot be solved, the error will remain on the display screen. Only by eliminating the error can the production continue. The screen schematic diagram of the error alarm function is shown in figure 7.
Figure 7: Schematic diagram of the error alarm function

Using human-machine interface instead of mouse and keyboard, operators can operate the device without a long time of training, and can eliminate the possibility of operator error operation; The development of human-machine interface can realize the visualization of the control process, and human-machine interface can modify the formulation parameters online, archive and print the data to facilitate the troubleshooting, so it is widely used in modern intelligent control[7].

5. Conclusion
Automatic control technology and robot technology have been widely used in the production and manufacturing of automobiles, becoming one of the main methods of automobile manufacturing. The welding control system of automobile dashboard bracket designed in this paper has the characteristics of high safety performance and control precision, so it has high market application[8].

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Reference
[1] Zhao D 2018 Exploring the current status of laser welding on the body-in-white Science and Technology 36 1222.
[2] Yu P and Xiao S P 2016 Application and research of welding technology in automobile manufacturing Shandong Industrial Technology 13 20.
[3] Chivu O R, Rontescu C and Cicic D T 2015 Qualitative and quantitative comparisons on reconditioning by welding of crankshafts from auto industry. Materials Science and Engineering 95.
[4] Li Q 2017 Design of electrical control system for spiral welded pipe precision welding equipment (Yanshan: Yanshan University Press) p 17.
[5] Wu J 2011 Design of control system for automatic welding production line of pump truck boom (Changsha: Hunan University Press) p 41.
[6] Zhao P F and Zhang B C 2009 Design and implementation of S7-200PLC human machine interface Mechanical Engineering and Automation 135-136.
[7] Anonymous 2010 Weld seams improve auto body stiffness and reduce weight Assembly 53.
[8] Li D Y and Chen G 2018 Design of control system for concrete mixing plant based on PLC and touch screen Automation and Instrumentation 33 1244-47.