Universal Automatic Spraying System Design

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Abstract—Automatic spraying system is mainly used for automatic spraying operation in the field of industrial manufacturing, painting and surface coating. This system realizes the automatic application of paint, paint or other surface coating materials through the use of mechanical devices and control systems. Its main structure can be divided into: painting machinery, paint supply system, control system. These components work together to achieve an efficient, consistent and safe painting process. Different types of automatic spraying systems may have different structures and components, depending on their specific applications and requirements. With the improvement of environmental protection and quality requirements, the automatic spraying system is also put forward higher and higher requirements. In view of the low efficiency of production and the great harm of manual spraying to human body, a general automatic spraying system is designed in this paper. the device has five degrees of freedom, flexible operation and two degrees of freedom control of the wrist. The advantage of directly improving the quality and effect of spray painting can significantly improve production efficiency and reduce labor costs.

Keywords-spraying robot; five degrees of freedom; overall design,;automatic

1. Introduction

Universal automatic coating systems are mainly used for automated spraying operations in industrial manufacturing, painting and surface coating. There are several important reasons for designing universal automatic coating systems, which reflect the need for efficient, flexible, cost-effective and high-quality production in the industrial and manufacturing sectors. The following are some of the main reasons for designing universal automatic coating systems: Versatility and flexibility: Universal automatic coating systems are designed for use in multiple industries and applications. This versatility and flexibility allows it to handle workpieces of various shapes and sizes to meet different manufacturing needs. Increased productivity: The automated spraying system can perform the coating task at a faster speed, which greatly improves productivity compared to manual operation[1]. The universal design allows these systems to be adapted to a variety of production environments, further increasing overall efficiency. Reduce human error: By adopting automated systems, the risk of human error can be reduced. The universal automatic spraying system performs the task through a pre-programmed path and parameters, reducing the reliance on manual operation, thus reducing the

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possibility of coating quality being affected by human factors. Consistency and accuracy: The universal automatic spraying system is equipped with advanced control technology and sensors to provide high precision and consistency in spraying operations. This helps ensure that each product has the same coating quality and reduces the rate of nonconforming products. Cost effectiveness: Although the investment in automated systems may be higher, they are generally more cost effective in the long run. By increasing production efficiency, reducing scrap rates and labor costs, universal automatic spraying systems help improve the economics of overall manufacturing. Adaptability and future expansion: The universal design makes it easier for these systems to adapt to future industrial changes and new production requirements. This adaptability helps companies stay competitive in a changing market environment. Overall, the design of a universal automatic spraying system can meet diverse production needs, improve production efficiency, reduce costs, and ensure product quality and consistency. This is very important for the pursuit of modern manufacturing enterprises.

2. Overall scheme of spraying robot

In the workpiece spraying operation, the robot has two working modes: one is workpiece movement / spray gun sweeping, and the other is gun movement / workpiece fixing. In working mode 2, the workpiece is fixed on the conveying line, and as the conveyor belt enters the spray operation area, the workpiece is in a static state during spraying, and the spray gun can sweep the workpiece according to the predetermined trajectory to realize automatic spraying. The method has the controllability to the coating material, fixing the position of the workpiece is beneficial to the adhesion of the coating, the quality of spraying paint is greatly improved, and the spraying path is easy to plan and control, and the spraying robot can change the spray attitude at will. To adapt to a variety of surfaces of various workpieces. In order to meet the design needs of the car body, the car body is sprayed, because the size of the car body is large, and the position is not easy to change, so the working mode 2 is adopted in the design: spray gun moving / workpiece fixed. At present, there are three driving modes of industrial robot, which are hydraulic drive, motor drive and pneumatic drive. The hydraulic transmission system has the advantages of stable operation, reliability, small inertia of action parts, fast response speed, good performance at low speed, easy to realize stepless adjustment, simple operation, simple control, but large volume[2]. Pneumatic transmission has high response speed and is widely used in CNC machine tools and other equipment, but it is troublesome to maintain because of pipeline leakage. This design adopts the form of motor transmission, which has the advantages of simple power source, small load, large speed regulation range, no piping, convenient maintenance and use, and long service life, so this subject uses motor transmission. Through the comprehensive analysis of the structure, the graphics of the structure and the distribution of degrees of freedom are obtained. As shown in figure 1.

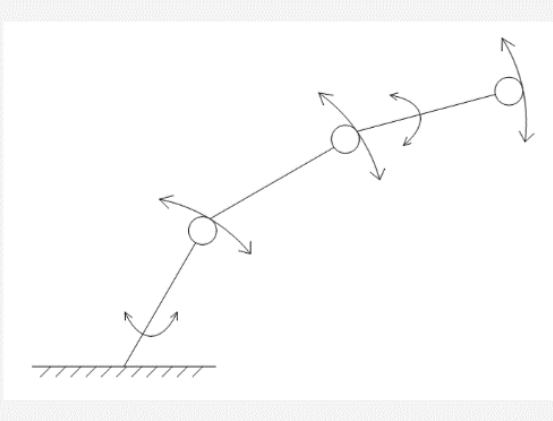

Figure 1 Freedom of spraying robot

3. Overall design

3.1 Overall Design Parameters

The following main design parameters are proposed in order to apply parts on sprayed surfaces as small as car shells:

1)Weight of sprinkler: 3kg.

2)Number of degrees of freedom of manipulator: 5.

3) Motion parameters:

a) *Base rotation:* angular velocity 3.14rad/s.

b) *Support rod pitch:* linear speed 0.35m/s.

c) *Top rod rotation:* Angular velocity: 3.14rad/s.

4) Exercise stroke:

a) *Base rotation:* 360 °.

b) *Support rod pitch*: 60 °~ 120 °.

c) *Upper pitch:* 0 °~-90 °.

d) *Wrist rotation:* 0 °~ 360 °.

3.2 Design Principle

The structure adopts articulated structure as a whole, which has the advantages of simple transmission principle, compact structure, small area and large operating space, and can bypass some obstacles of the base. The waist and wrist joints of the robot are articulated, which is very

beneficial to some work which requires fine operation, accurate positioning and operation at the same time, simple and fast operation[3].

3.3 Transmission Design

Because the base has to drive the whole mechanical arm, the inertia and weight are very large, and the torque of the servo motor is usually very low, so it uses a high-power DC motor, which decelerates through the gearbox and then drives the waist of the robot. The DC motor is fixed on the shell of the base to reduce the speed and provide more torque by way of reducer. The motor is fixed on the box, and the torque output of the motor will be transmitted to the deceleration device, resulting in a reaction, because the base is fixed on the floor, so it drives the box and the parts above to rotate[4]. Figure 2shows.

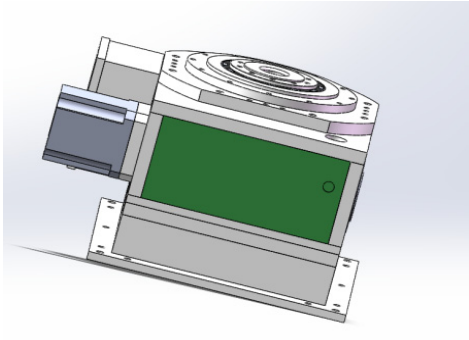

Figure 2 Spraying robot base

3.4 Joint Design

The wrist, also known as the wrist, is the part that connects the arm actuator sprinkler. Its function is to take the arm and waist as the terminal actuator, complete the three position coordinates in the workspace, and then complete the attitude coordinates of the end actuator in the workspace through the wrist. The waist structure is used to connect the base to the arm. As shown in figure 3.

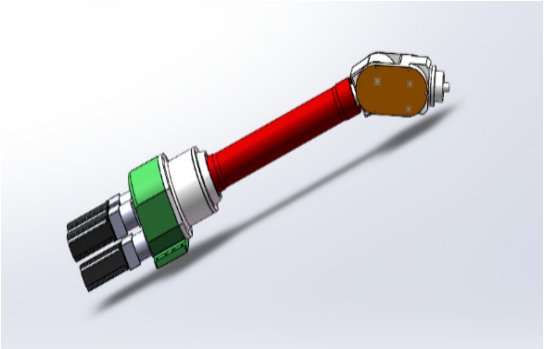

Figure 3 Spray the robot wrist

3.5 Arm Design

The design requirements of the arm frame: its structure and size must meet the requirements of the workspace; according to the force characteristics and structural characteristics of the arm, the cross-section shape of the arm should be reasonably selected and the materials with high strength and light weight should be adopted. Minimize the self-weight of the arm and the inertia and torque relative to the hinge rotation axis, thereby reducing the load of the transmission mechanism: reducing the dynamic load and collision during operation, and increasing the response speed of the action; minimize the motion error caused by mechanical clearance, so that the stiffness and accuracy of machinery are improved [5]. As shown in figure 4.

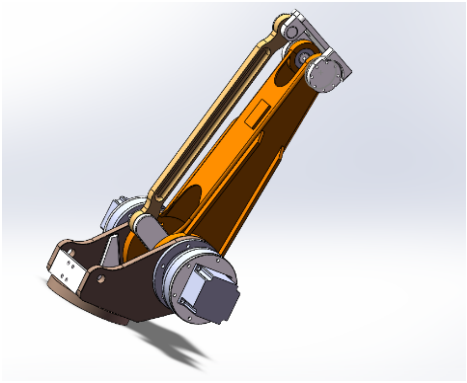

Figure 4 Spray the robot arm

3.6 Overall Design

Its structure is as follows: the waist motor M1 is directly driven by the harmonic reducer to rotate the waist, and the arm motor M2 is installed on one side of the arm joint, and each of them is swayed by the harmonic reducer. The forearm and the wrist are connected with the harmonic deceleration device by rotating motors M3 and M4, and the wrist swing is realized through the motor and the double output shaft drive[6]. This is shown in figure 5.

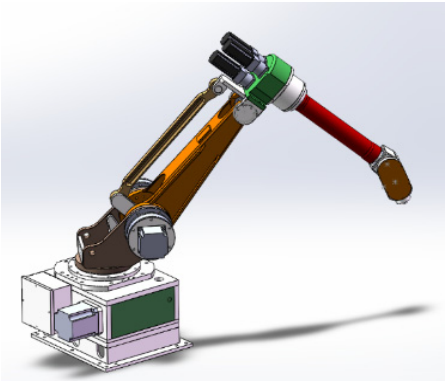

Figure 5 Overall design of spraying robot figure

4. Hardware system composition

Industrial control computer is widely used in many control systems because of its intuitive operation, high control precision and strong anti-interference ability. However, because the working environment of the spraying robot is complex, the working environment is complex and the workspace is limited, so the design of the control system has the characteristics of small size, simple operation, reliable work, strong anti-interference ability and so on. PLC is a special process control equipment which integrates automatic control, computer and communication technology. As the motion control system of upper computer and lower computer, PLC has the characteristics of low price, high reliability, strong anti-interference ability and long fault-free time, which not only makes it lighter and more flexible, but also has smaller size and lower cost. The system adopts SIMATICS7-1200series PLC[7], CPU 224as CPU,14 input and output, and RS-485 communication interface. In practical application, the host computer needs to input 3 (including 8-bit input module EM221) and 1 Amax D expansion module (that is, the module EM231 has 4 modular inputs). In the lower machine, in addition to the CPU224, there are four output expansion modules (i.e., the module EM222 with 8-bit output) and an Amax D expansion mode (also using the module EM231).

The control system includes: the host is connected with the console, which includes a series of control switches and potentiometers to receive the data of the operator; the communication between the host and the lower computer transmits the obtained information to the lower computer. At the same time, the host receives the temperature, position, angle and other states from the lower computer, and connects with PLC to realize the accurate display of the data. The camera installed on the robot transmits the working scene to the monitor of the console in real time, and realizes the real-time feedback to the working status of the machine. The work of the lower computer is mainly to perform the operation. The system should not only accept the action commands from the host, but also use the relay group to control the action of the DC motor together with the output expansion module[8]; at the same time, the analog signals such as temperature, position and angle are collected, and the analog values are converted into digital signals. By communicating with the host computer, the data is transmitted to the upper PLC.

PLC adopts RS485 standard interface and double differential data line, which has good anti-interference ability and long communication distance. The data signal transmission medium connected with it is mostly cable or cable, which has larger transmission capacity, longer transmission distance and better anti-interference performance, but its installation technology and minimum bending radius are higher. And the optical cable is easy to break when the optical fiber is twisted, which brings hidden trouble for use and high cost. Therefore, the system chooses a low-cost, easy-to-install wired transmission medium, because the working distance of the system is short, the signal transmission distance is short. After testing, the cable completely meets the requirements of the system[9].

5. The design of software system

5.1 Control Flow of The Control System

As shown in figure 6.

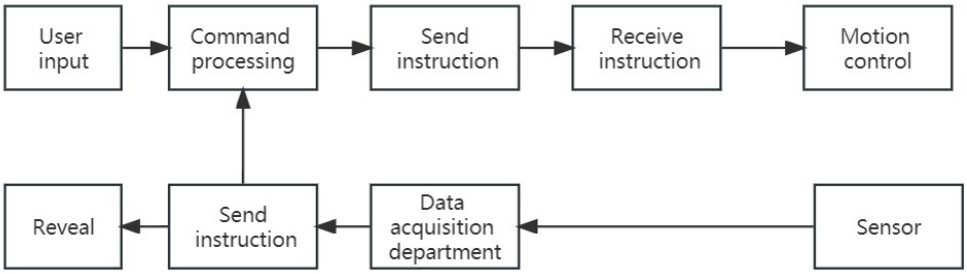

Figure 6 Control system flow chart

The control scheme of the system is as follows: the user inputs the robot reference input signal to the superior PLC through the operating platform, and the PLC processes it, converts it into a control signal and transmits it to the subordinate PLC, while the lower PLC converts the received signal from the upper computer into a switching control signal to control the DC motor installed in the machine[10]. At the same time, the lower computer collects the sensor from the scene, and after processing it, converts it into data and sends it to the upper computer, which obtains the field data from the lower computer and displays it with a digital tube.

5.2 Control the Program Flow of the System

According to the working needs of the mobile robot, Program execution stage In the program execution stage, PLC scans the program in order to execute. If the program is represented by a ladder diagram, it is always carried out in the order of first up and then down, first left and then right. When the program jump instruction is encountered, the program is decided whether to jump according to whether the jump condition is met. When the instruction involves the input and output states, the PLC reads from the input image register and the component image register, performs operations according to the user program, and the results of the operations are stored in the component image register. For a component image register, its contents change as the program executes. we first determine the working relationship between the motors, draw the program flow diagram, and use the input and output logic relationship of PLC to compile the ladder diagram. Figure 7 Programming flow.

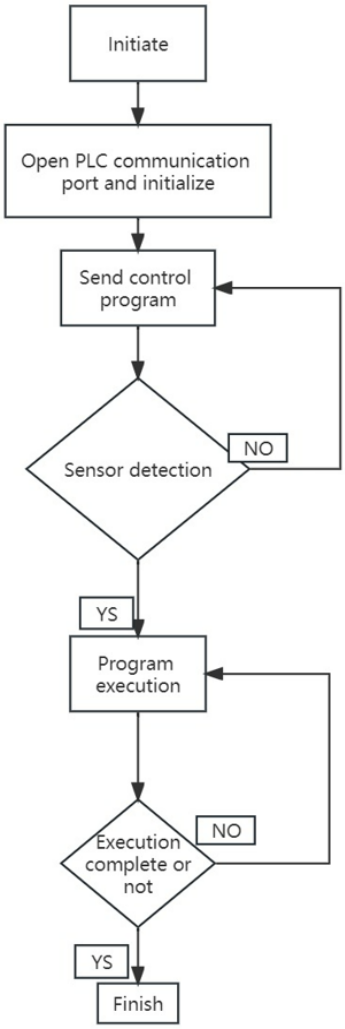

Figure 7 Program flow chartt

6. Conclusions

The automatic spraying system can improve production efficiency and solve the harm of toxic gas to workers in manual spraying. Its system is able to cope with different working environments, and the automatic spraying system can adapt to different products and coating types, providing manufacturers with greater flexibility to meet special market needs and customer requirements, solving the existing system only for a single production. By reducing manual operation, reducing paint waste and automatic spraying systems through precise control and monitoring, ensure coating uniformity and quality consistency. Through precise coating

supply and control, automatic coating systems can reduce paint waste, reduce the risk of environmental pollution, and promote sustainable production. Universal Automatic coating systems help manufacturers produce and deliver products faster by increasing efficiency, responding to fluctuations in market demand, thereby reducing costs and ensuring quality. Overall, automated coating systems have brought significant social and economic impact to the modern manufacturing and surface coating industries by increasing efficiency, reducing costs, ensuring quality, and fostering technological innovation.

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