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Research Article

The Review of the Welding Robot's Precision

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Abstract: Welding is an significant link in industrial production, and it is known as the "industrial tailor". However, welding fume, arc light, and metal spatter cause a harsh welding working environment, and the quality of welding has a decisive influence on product quality. Low production capacity, difficult recruitment, and low profits have become drawbacks for the development of the welding field. Combining traditional welding with robots can solve these drawbacks and increase the precision of welding. Welding robots are industrial robots engaged in welding and are mostly used in large-scale manufacturing fields such as automobile manufacturing. Welding robots are divided into spot welding robots, arc welding robots and laser welding robots. In addition, body accuracy and control accuracy are the two main factors that affect the robot welding accuracy. In this case, the sensing technology of welding robot is also essential.

Keywords: Accuracy; Welding; The structure of the welding robot; Sensor

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1 Introduction

1.1 Welding robot

The welding robot, as shown in Figure 1, is defined as a usage of mechanized programmable tools, which completely automate a welding process by both performing the weld and handling the part. The principle of the welding robot is to adjust the voltage, the current, and the gases to melt the solder wire in a constrained temperature. Welding robots can integrate the control system, the sensor detection system, and the mechanical system, as shown in Figure 2.

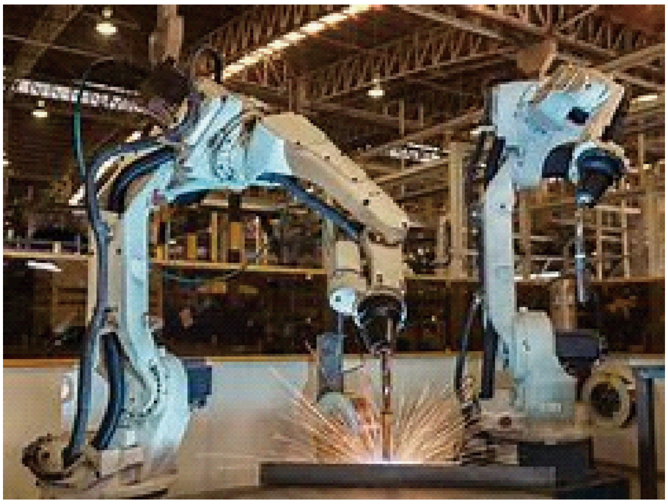

Figure 1. Welding robot

Among them, the control system is a significant part of the welding robot, including memory function, teaching function, connection with peripheral equipment, man-machine interface, sensor interface, position servo function, fault diagnosis and safety protection function. In addition, the control system also has hardware components, control computer, teaching box, operation panel, digital and analog input and output, printer interface, sensor interface, axis controller, auxiliary equipment control and communication interface.

Traditional robot sensors include position sensors, speed sensors, acceleration sensors and other sensors. In addition to these, the welding robot also uses laser sensors, vision sensors and force sensors, and realizes automatic tracking of welds and automatic positioning of objects on automated production lines and precision Assembling operations to improve the robot's operational performance and adaptability to the environment.

The welding robot's mechanical system are basically joint robots, and most of them have 6 axes. The 1st, 2nd, and 3rd axes can send the end tool to different spatial positions, while the 4, 5, and 6 axes solve the different requirements of the tool posture. The mechanical structure of the welding robot body mainly has two forms: one is a parallelogram structure, and the other is a side-mounted (pendulum) structure. The main advantage of the side-mounted structure is that the upper and lower arms have a large range of motion, so that the working space of the robot can almost reach a sphere. Therefore, the robot can be hung upside down to work on the rack to save floor space and facilitate the movement of objects on the ground. However, this kind of side-mounted robot has a cantilever structure on the 2nd and 3rd axis, which reduces the rigidity of the robot. It is generally suitable for robots with smaller loads for arc welding, cutting or spraying. The upper arm of the parallelogram robot is driven by a pull rod. The pull rod and the lower arm form two sides of a parallelogram, and the clamping system of the robot is used to keep the precision of welding procedure in different angles to ensure the quality of welding

In addition ,the motion of each joint (ie each axis) of the welding robot is ultimately attributed to the rotation of the corresponding drive motor of each axis, that is, the rotation of the servo motor; and the robot motor servo system puts forward high requirements, which can be roughly summarized as the following one aspect: high precision, in order to improve production efficiency and demand; wide speed range (ratio of the highest speed and the lowest speed that the motor can provide under rated load), the robot can operate normally within a certain range; low speed and large torque.

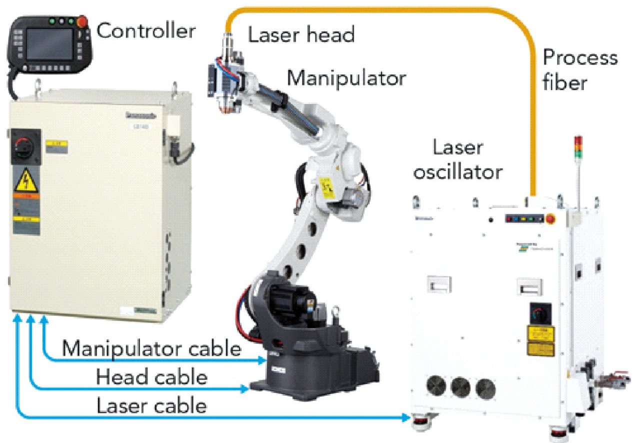

Figure 2. The structure of the welding robot

1.2 The precision of welding robots

The widespread aging around the world, as shown in Figure 4, has led to a shortage of employed population. Because of the lack of human labor, many industries have to use robots to complete tasks. However, it is difficult for robots to have high accuracy. Since most manufacturing industries have high requirements for product accuracy, the requirements for robot operation accuracy will be very high, such as welding robots in the welding industry, and Precision design of the robot is directly related to the quality and production efficiency of production. Therefore, if the accuracy of the robot is not high because the product will be quality and production efficiency without achieving the desired effect and lose a lot of time and money. People must find out the factors that improve this accuracy to save costs and improve efficiency of the production.

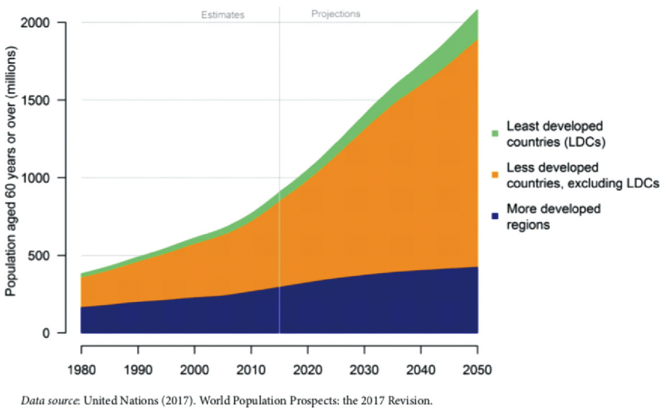

Figure 3. Global aging trend

With the future trend of automated production in the world , as shown in Figure 3, the adoption of welding robots has ensured an increase in productivity on the welding line. It reduces serious work injuries, improves the speed and accuracy of order execution, increases up time, and reduces costs. The automotive, manufacturing, and metal industries have adopted automated welding technology to reduce costs, save time, and improve welding quality. Another advantage of robotic welding is to help reduce the workload of employees and work with them to increase efficiency. The need for welding robots eliminates the need for manpower and ensures excellent operation by effectively and efficiently performing repetitive tasks.

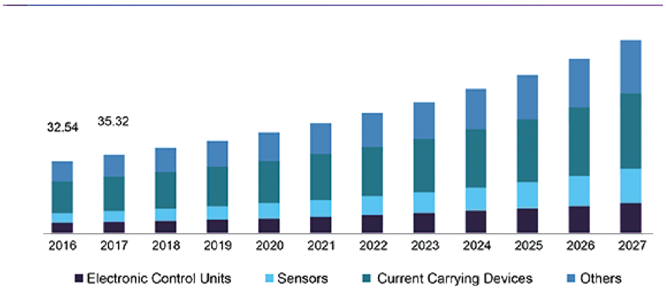

Figure 4. Automotive electronic market size

In addition, the huge investment in robotics research and development activities in various industries encourages the use of new advanced technologies to develop welding robots, as shown in Figure 5. Welding robots can be customized to meet specific requirements, such as online seam tracking and remote monitoring, and effective body structure to improve compatibility with humans through the use of innovative technologies.

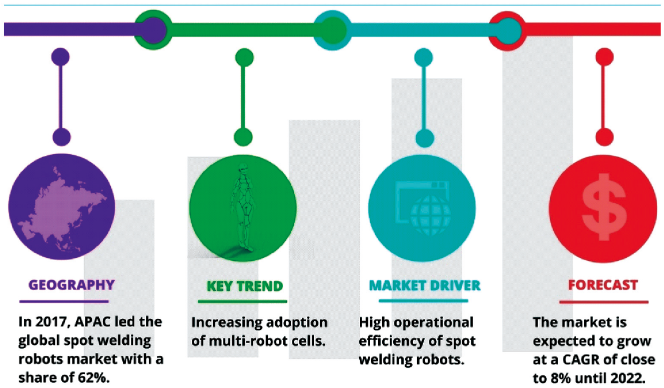

Figure 5. Global spot welding robots market

Moreover, the loss and stagnation of human labor caused by the impact of the global epidemic, as shown in Figure 6, in 2020 will further arouse global attention to automated production. The main reason for adopting multi robot control in industry is the possibility to reduce production cost by having robots working in parallel, especially for low speed processes as arc welding. Other advantages are that multiple robots can be controlled by one controller, which saves floor space, improves collision avoidance performance, and reduces cycle time. Further, in the arc welding is performed by simultaneously from different directions on the same welding object, a symmetrical heat distribution can be obtained. Therefore, the accuracy of welding robots needs to be improved to meet people's required use standards[1-5].

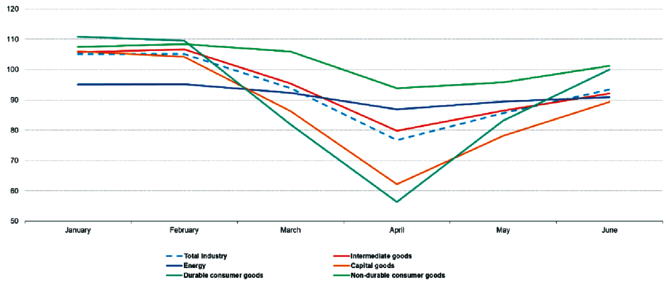

Figure 6. Development of industrial production

2 The welding robots

2.1 The development of the welding robot

In 1949, the United States applied for teaching reproduction technology. This technology established the control technology of most modern teaching robots. The essence of this technology is to first complete the task path by artificially assisting machinery, and the machinery can record the joint rotation angle and other related data can come from the trained. Then in 1959, the United States designed and produced the world's first prototype of an industrial robot. Three years later, the first robot "VERSTRAN" for practical work was produced by the American company AMF. This incident triggered a worldwide boom in the robotic research, so many countries including the United States start to implement corresponding policies to support the research and production of industrial robots. First, the United States continues to invest and accelerate the development of industrial robot applications. Following the United States, the United Kingdom and Germany implemented a subsidy policy for industrial robot research and development, enforced the research and development of industrial robots, and specified positions to greatly accelerate the practical process of industrial robots. Japan has made up for its own development process by introducing mature and advanced technology of industrial robots in the United States, so that Japan now has a pivotal position in the development of industrial robots in the world. Industrial robots are so appreciated because of their long working hours and strong applicability. Among them, welding robots have the highest status, as shown in Figure 7.

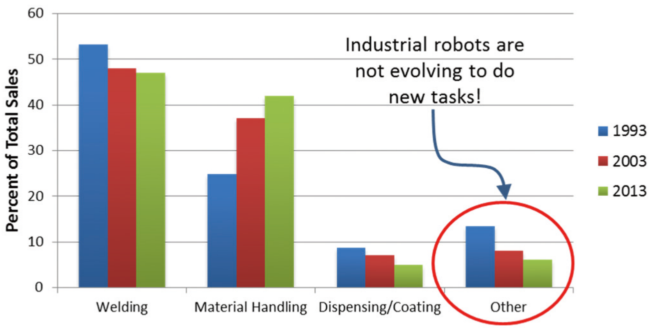

Figure 7. Industrial robot sales in North America

2.2 Key sensing technology of welding robot

Current robots can have a flexible posture and human-like sensory functions are inseparable from the blessing of sensors. Sensors give robots a variety of perception capabilities such as vision, force, touch, smell, and taste. The robot's perception function can also be used to detect the internal working status of the robot itself. By detecting and understanding the position, speed, temperature, load, voltage and other information of each joint, it can effectively ensure and improve the operation and sensitivity of the robot itself.

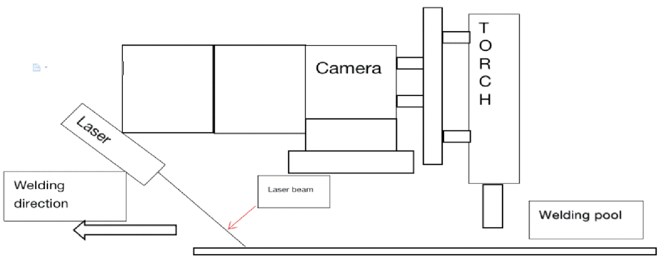

Figure 8. Robot welding structure

The sensing technology of welding robot is mainly divided into two kinds. The visual seam tracking sensor, as shown in Figure8, is one of the foundations of welding robot sensing system. In order to obtain the three-dimensional contour of the welding joint and overcome the interference of the arc during the welding process, the robot welding tracking and recognition technology usually uses active vision methods, such as laser and structured light, to correctly guide the robot welding and follow the actual welding seam to the end of the torch To complete the required trajectory movement. Since the energy of the active light source used is mostly smaller than that of the arc light, the sensor is generally placed at the front end of the welding torch to avoid the interference of direct arc light. The active light source is generally a laser beam scanned by a single-beam or multi-beam laser domain, and the processing is stable, simple, and practical.

Structured light vision, as shown in Figure 9, is another form of active vision welding seam tracking. The corresponding sensor mainly consists of two parts: one is a projector, which uses its radiation energy to form a projection light surface; the other is a photoelectric position detector, often using a surface Array CCD camera. After they are assembled in a certain positional relationship, and matched with a certain algorithm, they constitute a structured light vision sensor, which can perceive the three-dimensional information of all visible points on the projection surface. It can be considered that the trajectory of a spatial weld is composed of a series of discrete points. the density of which is determined according to the needs of control. The origin of the welding seam coordinate system is established on these points, and the sensor measures one welding seam point each time. The pose and the pose heuristic information of unknown weld points can be obtained and the guided robot welding gun completes the tracking of the entire smooth continuous weld. In order to move the welding gun along the weld path, the teaching pendant is used in a traditional robotic welding system. In addition, it is necessary to set welding parameters, start and extinguish the arc, control the shielding gas, and use the robot controller to program smooth welding at the same time. But this often leads to torch positioning errors and unsatisfactory welding quality[5-10].

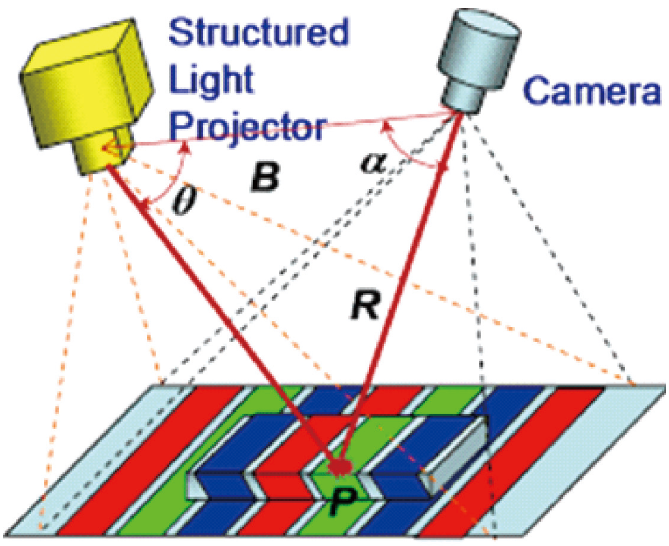

Figure 9. 3D Object in the Scene

3 Precision Analysis of Welding Robot

3.1 Accuracy of the robot body

The body mechanism and high-precision components, high-precision reducer and servo motor play a vital role in the robot. The structure of industrial robot needs to be optimized in the later stage, and the ideal precision and strength can be achieved through continuous optimization design.

When designing the fuselage of a welding robot, it should be noted that the body structure must have sufficient strength, rigidity and stability; structural body is not only to meet the requirements of flexible movement, for example, avoid occurrence and self-locking during design or the problem of jamming, and enough space should be left to install various power lines. The signal line should ensure the safety performance of the robot because the robot is very fast during the welding process. For example, limit switches are installed at the limit positions of each joint of the robot, so that when the robot's work exceeds the working range, as soon as the limit switch is touched, the drive source can be automatically cut off to protect the relevant the safety of people and the equipment[10-13].

The analysis and selection of materials, as shown in Table 1, is one of the important steps in the design of the robot body. Most of the robot rods e are parts that move frequently. On the one hand, it requires a high speed when working. Therefore, the material of the rod is preferably a light material to reduce its own weight and inertial force; on the other hand, because the robot is often at a high speed. In the state of reciprocating motion, it is bound to be accompanied by vibration, and the welding work requires good stability and high precision, that is, the material of the robot should have the characteristics of high rigidity and good vibration resistance. Comprehensive considerations, the robot rod determines the material with higher specific strength. The higher the specific strength of the rod material, the higher the strength of the rod under the same weight. After analyzing the properties of various materials commonly used at present, it is found that among the materials that conform to the robot motion rods, the hard aluminum alloy has the better performance, so it is used as the manufacturing material of the robot motion rods, such as the robot arm wrist; The base and waist of the welding robot play an important role in the overall working stability of the robot, good anti-deformation ability, high strength and so on. Compared with commonly used materials, it is found that alloy structural steel has better performance in these aspects and can satisfy. Therefore, alloy steel is selected for the material of the base and waist[13-15].

Table 1. The analysis of different materials

Material	$E/\times10^5$ MPa	$\rho/\times10^3$ kg/m^3	$(E/\rho)/\times10^7$ m^7/s^7
40Cr	2.10	7.80	2.70
LY12	0.72	2.80	2.60

3.2 Control Precision

In the improvement of the accuracy of welding robots, the second most important factor is the control accuracy of the robot. The control system of welding robot is composed of several parts, including memory function, teaching function, connection with peripheral equipment, man-machine interface, sensor interface, position servo function, fault diagnosis and safety protection function. The high precision control part includes: link cable, transformer, cable, end device hand grab, power switch, stop button, power supply, main board, servo amplifier and so on. The control accuracy ensures that the robot can run accurately, and it can also make up for the error of the body accuracy. Therefore, the robot control accuracy is significant. The wire feeding control system and gas mixing control system of the welding robot, as well as the voltage and current control system directly determine the quality of the welding workpiece of the welding robot, the servo motor control system and the driving system determine the stability of the welding robot. The sensor control system determines the safety and stability of the robot operation, and at the same time improves the stability of welding[15-17]. Therefore, improving the stability of the control system determines the accuracy of the welding robot.

It has been found that model-based control (Sciavicco and Siciliano, 2000) is very significant in robotics, which can meet the contradictory requirements of performance improvement and cost reduction.

Continuous development for more complex kinematics and dynamic models, more complex multiple-input multiple-output (MIMO) control scheme, a greater change in static and dynamic model parameters, increasing the level of noise and interference, more low mechanical Intrinsic frequency and expanded non-linearity. Even if a large amount of academic research has been conducted in all these areas, a large amount of applied research is needed to further improve the model-based robust control of industrial robots[18-25].

4 Conclusions and discussions

The application of welding robot technology has strongly promoted the progress of world industrial technology. Especially welding robots play an extremely significant role in high-quality and efficient welding production. This paper mainly focuses on the development of welding robots, the analysis of welding robot accuracy, and the research overview of improving the overall accuracy of welding robots. The conclusion points out that the robot welding accuracy is mainly affected by the body accuracy and control accuracy. Among them, the development of sensor technology plays a key role.

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