Investigation of Laser Welding Seam Tracking Based on Visual Sensing

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Abstract. Seam tracking ability is a key for automatic laser welding system. The status of laser welding seam tracking technology is introduced in this paper. The principle and characteristics of the sensors particularly vision sensors used in the automatic laser welding are analyzed. Some control algorithms of automatic laser weld seam tracking system are also discussed.

Introduction

Laser welding is one of the most important methods in the field of modern manufacturing. With the development of modern manufacturing technology, laser welding technology has been applied more and more frequently. Modern production of laser welding technology has made new demands. Modern enterprise has to consider how to ensure the laser welding quality, improve production efficiency and the working conditions, cut down the cost in manufacture.

Robot welding is an important developing direction of welding automation, and automatic seam tracking technology is one of principal research domains [1]. In robot automatic laser welding，it is very important to develop and apply weld seam tracking system. Therefore, problems of weld seam tracking technology have become increasingly prominent. It has become an important research subject in the field of domestic and international laser welding automatic control.

Welding process is a multivariable complex system, which is nonlinear, time-varying and affected by random disturbances. Due to the influence of different kinds of factors, the current seam center often changes. For example, because of strong radiation, plasma, high temperature, dust, spatters, groove conditions, machining error, the clamping precision, surface state and thermal deformation of the workpiece, laser beam often deviates from weld center. Welding robot should have the ability to detect weld seam, adjust the welding path and welding parameters, and ensure the laser beam to follow the weld center accurately.

Summary of Laser Weld Seam Tracking System

To realize automatic welding seam tracking in a variety of welding conditions, it is required that the weld seam tracking system should have excellent intelligence. The key for weld seam tacking system is to solve the problems as follows [2].

Automatic Tracking and Closed-loop Control. The best way should be considered to make the system have the strongest sensitivity, real-time performance. The mechanism motion control would be of great convenience to control the laser beam to follow the seam trajectory in real time.

Controller. The controller hardware should be strong functions and low-cost. Researchers want to work out the most reasonable and effective principle and method to coordinate different degrees of freedom of motion control.

Mechanism. It is necessary to work out the most reasonable freedom configuration and structure to ensure that the organization is the most convenient and flexible movement. Fig.1 shows the visual sensing system for welding and quality tracking. Because of the laser energy from the laser beam welding base on the unique structure of the laser transmitter, we can design a coaxial detection

mode between a monitor and a laser emitter so as to achieve the purpose of coaxial visual sensing system. Also, a high speed camera could be used to capture the instant molten pool images. The system which is used to identify the welding seam deviation information can be simplified into four parts: sensors, controller, servo system and actuator. The system with sensors can detect the position deviations of the laser beam from the weld position. With the processing of the control system, it outputs control signals. Then servo system drives the actuator, and the laser beam goes back to the weld position so as to ensure that the welding point is always in the real seam line.
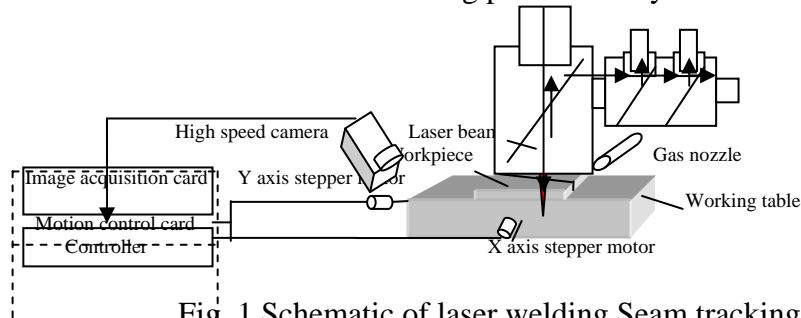

Fig. 1 Schematic of laser welding Seam tracking system

Sensors of Weld Seam Tracking System

In the process of welding, sensors play a key role in seam tracking and it directly affects seam tracking precision. Sensors used in seam tracking are the most important part in seam tracking system. With the rapid development of sensor technology, many types of sensors have appeared. According to the different ways of obtaining information, sensors can be divided into indirect type sensors and direct type sensors [3]. And indirect type can be divided into contact and non-contact. Contact type sensors consist of probe contact mode, probe touch mode, while Non-contact type sensors consist of optical method, ultrasonic method and electromagnetic mode.

Among different kinds of seam tracking sensors, there are mainly such kinds of seam tracking senors as follows [4]: mechanical - electronic sensor, electromagnetic sensor, ultrasonic sensor and vision sensor. Among the various types of sensors used in welding automation, vision sensors are widely used for automatic seam tracking and quality control of welding processes. Advantages by using vision sensor for obtaining the characteristic information of weld seam are a large number of weld seam information, high sensitivity and precision, strong anti-jamming ability.

Vision sensor system is an important part of the robot welding detection system which will directly affect the precision and quality in welding process. If the image acquired by vision sensor is not perfect, weld seam tracking would be difficult, and quality of welding joint would be so bad[5].

Fig.2 shows the ability of the weld seam tracking system with vision sensor used to detect the seam in a workpiece. During the high power fiber laser welding, a camera was used to capture the molten pool images. After image processing, the characteristic information of keyhole and weld could be obtained, which were used to get the deviations between the laser beam and the weld center.
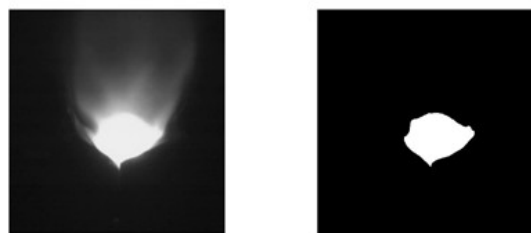

Fig.2 Original image of a molten pool and a keyhole image

Composition of Seam Tracking System of Robot Vision

Seam tracking system of robot vision system can be divided into three parts: information acquisition and processing system, controller, mechanical driving device [6, 7].

Information Acquisition and Processing System. Information acquisition and processing system is composed of a collection subsystem and information processing subsystem. Information acquisition and processing system is mainly used for information gathering and information processing. In order to reduce the disturbances of the welding process, a filter should be installed in front of the vision sensor. In the information processing subsystem, the user prepares image processing procedures and input to the system. The final output of system is the deviation information between the laser beam and weld.

Controller. The controller composes of software and hardware which receive the input deviation information from the information acquisition and processing system. By processing the image information, the controller outputs a control signal to the mechanical driving device so as to control the movement of the laser beam. Finally the controller can finish the task of the real-time correction of welding seam.

Mechanical Driving Device. Mechanical driving device consists of driver, motors, mechanical execution device. With the control information, it completes the corresponding action.

Control Algorithm of Automatic Weld Seam Tracking

Fuzzy Control. The basic principle of fuzzy control is shown in Figure 3. Fuzzy controller is the core part, as shown in the dashed box. Implementation process of Fuzzy control algorithm can be explained as follows. Samples of error signal E and error signal variation E_c are obtained by the computer, the two values are processed by Fuzzy quantification and expressed in the corresponding fuzzy language, while e and e_c are the subset of fuzzy language set from E and E_c. Fuzzy decision is made with E, E_c and fuzzy control rules R according to the synthetic rules of fuzzy reasoning. Fuzzy control value u is obtained, then u is converted to exact value and can control the object [8].
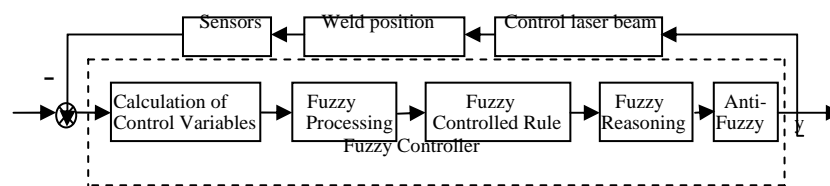

Fig. 3 Block diagram of fuzzy control system

Classical PID Control. The mathematical model will be subjected to interference effects. And parameters can not be adjusted or adjustment is not flexible enough. The simple application of classical PID control is difficult to meet the need of weld tracking. In a large range of error, welding process van be controlled by FUZZY-PID to rapid response adjustment. In a small range of error, the traditional linear PID control can be considered.

Neural Network Control. Neural network has the ability of self-learning, self-organization, fault tolerance, self repair, pattern recognition and retrieval. The popular application in seam tracking is BP neural network, Hopfield neural network and Algebra Reconstruction Technique.

Intelligent Control. Intelligent control makes combined using of fuzzy control, neural network and expert system control technology. Intelligent control which is used in a complex nonlinear system with uncertainty is a very good solution to nonlinear control problems.

Conclusions

Weld seam tracking system with vision sensor becomes a hot research in automatic laser welding. With the development of science and technology, the visual sensing technology can be used to detect the weld position accurately. Intelligent control techniques such as expert system, neural network, fuzzy control have been applied to control the laser beam for following the weld trajectory in real time.

Acknowledgements

Reference

[1] X.D.Gao, L.Mo, X.G.Zhong, D.Y.You and S.Katayama: Acta Physica Sinica. Vol.60 (2011), p.088105-1-8.

[2] Lu Xueqin, Zhang Ke and Wu Yixiong: Chinese Journal of Mechanical Engineering Vol.39(2003), p.80

[3] Liu Gao, Gao Bo and Zhang Dacheng: Automation technology and Application of Heilongjiang Vol.14(1995), p.1

[4] Zhang Hua, Hu Jing and Zhou Chunhua: Transactions of the China Welding Institution Vol.24(2004), p.51

[5] Xu Yanling, Yu Huanwei, Zhong Jiyong, Lin Tao and Chen Shanben: Journal of Materials Processing Technology Vol.212(2012), p.1654

[6] Gao Xiangdong, Ding Dukun and Zhao Chuanmin: Transactions of the China Welding Institution, Vol.2(2006), p.19

[7] De A, Parle D. *Science and Technology of Welding and Joining*, Vol.8(2003), p.340

[8] Hu Ronghua, Tu Keliang, Zhang Hua and Liu Guoping: 2010 Seventh International Conference on Fuzzy Systems and Knowledge Discovery,Yantai,China (2010). p.748