Robotics and Computer Integrated Manufacturing 56 (2019) 12–37

Contents lists available at ScienceDirect

Robotics and Computer Integrated Manufacturing

journal homepage: www.elsevier.com/locate/rcim

Review

Advances in weld seam tracking techniques for robotic welding: A review

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ARTICLE INFO

Keywords:
Seam tracking
Robotic welding
Sensors
Laser sensor
Vision sensor
Arc sensor
Controller

ABSTRACT

Use of sensors in robotic welding for controlling the weld quality leads to replacement of manual welding operation in dangerous work environment in presence of high temperature and fumes even in small or medium scale enterprises. The seam tracking operation is very essential for extracting weld seam position which can be fed to robot controller for instructing robot along the weld seam path. The seam tracking operation can be executed by different types of sensors having their own merits and demerits. In this paper, different sensors and techniques used for seam tracking task in robotic welding have been discussed in detail. Each sensor has different method or technology of weld seam feature extraction which have been described by different authors in different ways. The chief tasks for seam tracking have been found to be weld starting and end point detection, weld edge detection, joint width measurement and weld path position determination with respect to robot co-ordinate frame. Thus sensors have a very important role in robotic welding for fully automating the system with in process real time monitoring of weld process parameters with the sensor feedback. In further discussion the practical use of different sensors in industries with a comparison of their advantages and disadvantages have been discussed. This Paper presents the role of sensors in robotic welding and a detail study of methodologies of weld seam position and geometry feature extraction by different sensors typically used for weld seam tracking.

1. Introduction

The machines those can be utilized in place of human-beings for performance of a task in terms of both decision making and physical activity are termed as robots. The utilization of robot in industries leads to the term automation which implies the introduction of robot in the manufacturing processes for both physical production processes and processing information. The wide range of application of industrial robots include material handling to an extensive variety of production applications, e.g. quality control, welding and machining. A considerable measure of research work is going on in the fields, where precision of the robot is a major factor like in robotic forming, arc welding and metal cutting etc. [1–6]. With advancement of recent manufacturing technologies, it turns into an unavoidable pattern to acknowledge automatic, adaptable and intelligentized welding producing. As is well known, welding innovation has been created and advanced from the first hand-worked specialty to the advanced systemic specialized science. Examining and simulating intelligent activity and capacity of welder's operation is critical for improvement of intelligentized mechanical welding. Therefore, simulation and understanding a welder's activities by some clever machines, e.g. industrial welding robot is one of the most vigorously researched issues in the advanced welding technology. The use of industrial robots is essential in hazardous and poor working environment where reaching of human being is not possible like in ship building application, nuclear power plants, maintenance and repair works etc. Mechanical robots and motorized hardware have gotten to be crucial for modern welding for high-volume profitability since manual welding yields low production rates. For small or medium production volumes, automated generation yields the best cost per unit execution when contrasted with manual mechanization. Robotic welding frameworks bring different favorable circumstances, for example, make strides in efficiency, weld quality, adaptability and workspace use, and diminishes work costs in addition to focused unit cost [7–10]. Be that as it may, welding robots basically work in "teach and playback" mode in which they have no enough adaptability, particularly in welding process. Since welding as a process experiences numerous factors such as the mistakes of pre-machining, fitting of work-piece, and in-process defects, which will bring about variation in weld gap, the welding techniques must be balanced as per these progressions. Robots in instruct and playback mode have no such capacities and typically weld a weldment with bunches of defects and poor penetration. In this way, it is important to build up an automatic control framework for those welding robots working in instruct and playback mode [11,12]. A genuinely mechanical welding framework

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https://doi.org/10.1016/j.rcim.2018.08.003
Received 7 June 2017; Received in revised form 15 August 2018; Accepted 28 August 2018
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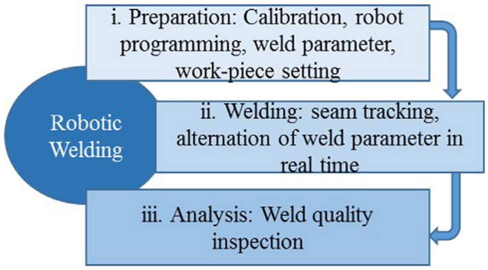

Fig. 1. Steps of robotic welding.

ought to have three foremost parts: sensors, which identify the state of welding procedure; a model of process, which gives the relationship between the welding factors and the geometry of weld bead; a control framework, which assesses the sensor information and changes the welding procedure factors utilizing the relationship in the process model [13–15].

1.1. Robotic welding

Welding process has been one of the most integral part of modern manufacturing process. Now-a days, the utilization of industrial robots is one of the chief sign of contemporary welding [16]. The integration of robot with welding process has advantages like: (1) The robotic welding can be very useful in terms of both cost and quality for small and medium production volume. (2) Consistency in performance by maintaining the quality for a long time. (3) Makes the process quite flexible and also can be utilized for other modern manufacturing processes. (4) Adaptation of variation in production line with variation in production volume (Easy adaptation to change in design and working environment). In automated welding generally three stages are there: (i) preparatory stage, (ii) welding and (iii) analysis as shown in Fig. 1 [17].

1.2. Need of sensor in robotic welding

To move the welding torch along the weld seam path, teach pendant used to be utilized in traditional robotic welding system. In addition to this, programming for setting of weld parameter, starting and extinguishing of arc and controlling of shielding gas and use of robot controller for smooth welding have to be performed simultaneously. But this often results in to error in torch positioning and unsatisfactory weld quality. These issues can be handled easily by the use of sensors for seam tracking and weld pool inspection [18]. There is an increase in demand of concept of intelligent robotic welding due to variation of part design, just in time and CAD customized flexible production approach. Sensor integration with the robot manipulator can improve the welding process in an intelligent manner [19]. The different aspects of automated robotic welding are shown in Fig. 2.

The introduction of sensors in production processes leads to a progressive step towards achievement of expanded adaptability with respect to volume of production, product variation and life cycle of product. The sensors in production processes can be utilized for optimization and process control of diverse machines and different machine tools. The sensors can also be used to expand the adaptability of the robot framework and empower the utilization of robots in irregular production which leads to recognition of various issues that must be understood effectively to coordinate sensors and enhance effectiveness of the system. But it has been observed that the actual use of sensors in welding processes is quite low except for high quality and tolerance requirements [20]. The primary use of sensors in welding operation is to control the weld parameter and the actions of robot. Pires et al. [17] described about development of seam tracking system as described in Fig. 3.

2. Sensors utilized for seam tracking

The sensors utilized for trajectory control of robot path in welding are generally based on arc sensing and optical sensing. But other sensors are also available like infrared sensing, ultrasound sensors, electromagnetic sensors etc. having their own method of characteristic feature extraction but have not been utilized in industries in wide range. The sensors can be utilized in different types of robotic welding.

Again various type of sensors are used in robotic welding for performing seam tracking and are represented in Fig. 4 according to their working principle.

2.1. Arc sensor for weld seam tracking

The arc sensor is typically designed for metal arc welding process and depends on a detecting technique which uses a key arc property, i.e. arc voltage and current features change according to the height of torch comprising of arc length and wire extension changes. The very reality of the arc fundamentally being used with advantages of its status as a modest and basic method, great continuous operability, and little defencelessness to the impact of wire electrode twisting, have made this approach famously material to different sorts of programmed welders and robots [21]. A general process of seam tracking by arc sensor is described in Fig. 5.

2.1.1. Developments models for arc sensor

Past studies developed mathematical expression showing relation between the torch to work-piece distance and the welding parameters like voltage current, wire feed rate etc. Julian [22] developed mathematical model for arc sensor considering its static and dynamic properties. In this model, the static properties, equilibrium conditions of wire feeding system and electric circuit have been utilized.

First an equation has been established utilizing the electric circuit parameters as shown in Fig. 6. Where, U represents the arc voltage, V_f is the wire feed rate, I is the weld current and H is the torch to work-piece distance. Based on the wire feeding system condition then another equation for melting rate has been established in terms of melting rate devoted by arc and the wire extension. Both the equations are combined to develop expression for torch work-piece distance. Experiments have been performed to compute the coefficients by regression analysis and the generalized equation developed is shown in Eq. (1).

$$H = (a_1 + b_1 V_f)I + (a_2 + b_2 V_f) \tag{1}$$

As because the arc sensor either rotates or oscillates at the time of

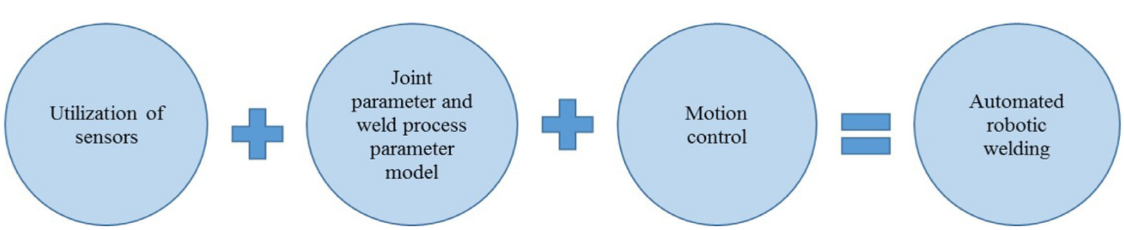

Fig. 2. Aspects of robotic welding.

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