

A Survey on Robotic Arm Applications in Industry for Welding Operation

Kishor Kumar Keshri¹, Manish Gangil²

^{1,2}Department of ME, Sri Satya Sai College of Engineering, RKDF University, Bhopal, M.P., India

Abstract: Robotics arm applications in industry have shown incredible growth to the bright future. By using robots, quick return on investment is a certainty, resulting in robotics application in most of the developed countries. Development of robotic arm in arc welding technology has widely diversified in terms of design and modeling, control system and sensing ability. The current trend for robotics arc welding applications in these categories is reviewed. Results show that developments in robotics application are affected by a lot of factors such as speed, flexibility, mobility, compactness, navigation, localization, and mobile platform. Highly developed system with characteristics of effective human decision making became favorable and has initiated an interesting intervention since the system is controlled by complicated neural network brain.

Keywords: Robotics arc welding; control system; design and modeling; sensing ability

1 INTRODUCTION

The importance of robotics to mankind has led to intensive research for over past decades. Market demands, environmental conservation, industrial automation, and personal services are among the major factors contributing to rapid evolution in robotics application. Recently, robots are used in automotive industry, military system, medicine, agriculture, aerospace, education, and entertainment. The level of competitiveness among robot manufacturers is very high in order to produce more productive, high-performance, cost effective and flexible robots. The demand for dynamic system for robotics application in arc welding has become greater in order to fulfill current industrial requirements. Keeping pace with that, there are advances in a lot of aspects such as seam tracking control system, playback ability, path planning control and the most notable is the trend towards intelligence robotics system [1].

Latest robotics inventions are great for certain narrowly specialized applications, but lack the flexibility needed to perform many of the tasks that come easily to humans or animals. Popularity of modern robots in science fiction for instance C3-PO in Star Wars indicates that the idea of having intelligent autonomous companion robot is possible [2]. Robotics technology in arc welding is synonym with industrial world. The application in welding emphasizes criteria such as consistency in quality, repeatability, and high speed with accuracy. In this paper, the investigation on current developments and applications of robotics arc welding

in terms of design, control system, and sensing ability are summarized.

2 CURRENT TREND FOR ROBOTICS ARC WELDING

Father of robotics, George Charles Devol has created the first industrial robots in 1954 [3]. Industrial robot continued to evolve and is directly influenced by the development of computer and massive production demand. At this time, development of arc welding robot in terms of design, control system and sensing ability are seen among engineers as potential areas because it will give highly positive impact to the whole production.

Design is in general defined as the establishment of a new algorithm wherein mathematical equation describes the physical parameters setup of the robot [4]. The most important part in arc welding process is the arc itself. Welding process consists of two types of control system which are manual control and automatic control [4]. There are a lot of differences between using automatic control and manual control in welding process that influence primary things such as in product quality level, number of production, error occurrences, hazardous working environment and total production costs.

Another important consideration in improving arc welding robot system is sensing ability [4]. Sensor that is integrated in the central welding system will convert the information from parameters involved into quantitative data such as digital signal, voltage and current.

2.1 Design and Modeling

An example of automated welding process was the work done by Lima *et al* who used structure for electrode voltage decrement in order to detect temperature change during the process [5]. As a result, the decided value of arc voltage for the welding process becomes more accurate. Creating control for right torch angle is also the important factor in ensuring high quality welding. The study by Silva *et al*. has established a parallel structure robot where their axes were independent to each other [6]. Therefore if any defect happened at particular axis, it would not influence the other axes, avoiding unnecessary use of high accuracy actuator. Damages will not spread to other axes, resulting in lower maintenance cost. Previously, Rubnovitz *et al* has used offline programming system in this experiment that improves productivity and efficiency

of welding process [7]. The total time needed for online programming tasks is reduced because the process of defining specific points is eliminated. The system also lowers the build up costs of the robot programming system.

By providing new opportunities for welding technologies, the applications of mobile robot have increased rapidly because it can replace human workers for tasks in hazardous working environment. Lee *et al.* has designed mobile welding robot with optimization based on workspace, which is 13% lighter than original design as shown in Figure 1[8].

Moreover, this robot is beneficial when it comes to building shipyard structures. However, design efficiency is lessened for about 4.9%. Chang *et al* has developed a method for mobile welding robot in detecting seam and plotting the 3D configuration of the profile [9]. It is tested by using straight line butt welding. The robot is also robust since it can work accurately with unpredictable profiles and rough bead surfaces. Tung *et al* explained in his paper image guided mobile robotic system that is capable of producing higher quality welding compare to manual work by experienced workers. After recognizing the defect part, robot will move to the intended welding path. Welding path is achieved by using newly introduced algorithm [10].

On the other side, Karadeniz *et al* observed the influence of welding parameters on welding penetration [11]. Generally, higher welding current and arc voltage lead to higher penetration depth. Welding current has stronger effect on penetration compared to arc voltage and welding speed. Control of weld shape is also important to ensure that welding process meet the requirement specification. Hongyuan *et al* has introduced a new reinforcement model which functions as feedback element [12]. The system can also be integrated with teach and playback robot in order to control welding current and wire feed rate. Apart from weld shape, uniform cross-section of bead profile is essential in maintaining product quality.

Bead profile forming is also critical for surface quality improvement. Therefore, optimal model in creating bead profile is an essential requirement in arc welding. Xiong *et al* found that shape of bead profile was highly affected by ratio of wire feed rate to welding speed [13]. Using best model in single bead section, perfect smooth surface is achieved by determining the centre distance of adjacent beads.

2.2 Control System

Control system in robotic arc welding is categorized in two; open-loop system and closed-loop system. Open loop system is the basic concept of any control system in welding process, while closed-loop system is the improved system. There are optimal control, adaptive control, and intelligent control.



Figure 1: RRX4 Mobile Welding Robot [8]

For instance, the work done by Daeinabi *et al* that developed an appropriate algorithm for controlling arc welding process in terms of seam tracking [14]. Using the algorithm, robots are able to perform good quality welding at any point and it can work in hazardous environment. Formerly, Murakami *et al* found that fuzzy logic controller reduce the vibration in tracking locus by using weld-line tracking control [15]. Another important factor affect product quality is bead width. Xue *et al* has introduced fuzzy regression system that is capable of maintaining welding quality by applying linear regression model together within the fuzzy variable of the triangular membership functions [16]. The system produces accurate measures for bead width. Sayyaadi *et al* in his work established the application of SCARA robot in GMAW [17]. Combinations of various methods are used in controlling the system such as feedback linearization, neural network, and fuzzy controller, resulting in improvement in system efficiency. Earlier, there is finding of intelligence robotics system named ROBOEDIT, an expert system specifically for floor adjustment [18]. The programming assistant is very efficient and result in increase of the number of production. The system is also capable of interpreting NC robot programming and English-like format.

Dung *et al* has introduced an adaptive nonlinear controller that improves wheel mobile robot detecting ability as shown in Figure 2 [19]. The system is powerful and hardly affected by disturbances from outside. Multivariable control introduced by Huisson *et al* contain of empirical state space model. It has the ability to identify reference steps and produce fair disturbance rejection [20].

Incompetent seam tracking is proved to be crucial for quality problems in welding process. Xu *et al* has established a new technology for seam tracking with self designed passive vision sensor that is capable of producing clear welding image for seam tracking [21].

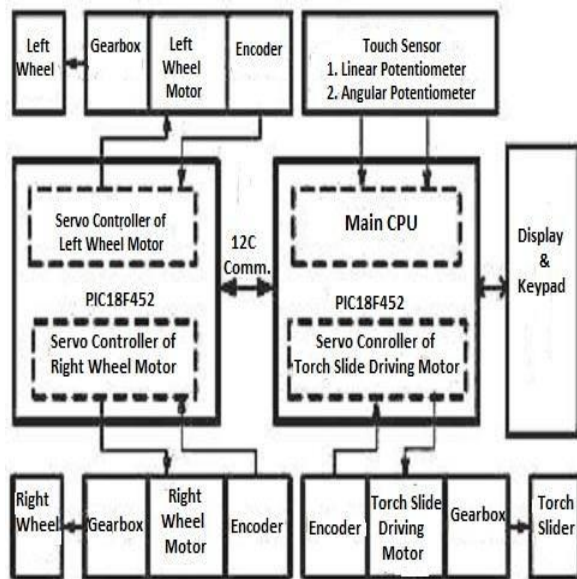


Figure 2: Control system configuration [19]

Then, a segmented self adaptive PID controller will monitor seam tracking in order to surpass seam forming quality requirements. Without doubt, intelligence control system is currently the best applied method practically. There are a lot of works done by researchers to create the modernized system. For example, Liu *et al* created an intelligent motion navigation method that capable of estimating zero accident path, thus minimized the energy utilization [22]. It gives significant impact in reducing power supply utilization. The programming also provides welding process of high quality and efficiency. Chu *et al* has produced an automatic control system which equipped with fuzzy gain scheduling controller that is capable of performing human tasks and shielded metal arc welding [23]. Zhu *et al* explained in his paper how the starting position of weld seam is detected using pattern match technology. Faster matching technology avoid time consuming process and the ability of the system give good technical support to the welding robot [24].

2.3 Sensing Ability

In welding process, sensor is used for estimating the condition of workpiece, followed by transforming the information to the robotics system for further action. Normally sensor is in form of portable micro-electronic device and play important role in the whole mechanized system. Park *et al* explained about mobile welding robot used for application in U-type cells [25]. System is equipped with touch sensor to modify the misplaced in positioning and dimensioning.

Nevertheless, the price of the robot is very high and it is also very heavy. Sweet *et al* has developed an application of vision sensor system using general electric P50 as shown in Figure 3 [26]. Welding robot produces excellent results for welding joints with 12mm at 12cm/s welding speed. Kim *et al* has established a system to calculate the position and orientation of end effectors. It adjusts 19 controllers' gains for 6-axis manipulator. The maximum magnitude frequency goes down by 54% [27]. Luo *et al* has developed a seam tracking controller that equipped with laser-based camera. The system has the capability to calculate the starting welding position and to employ two-point linear interpolation in order to detect missing seam points [28].

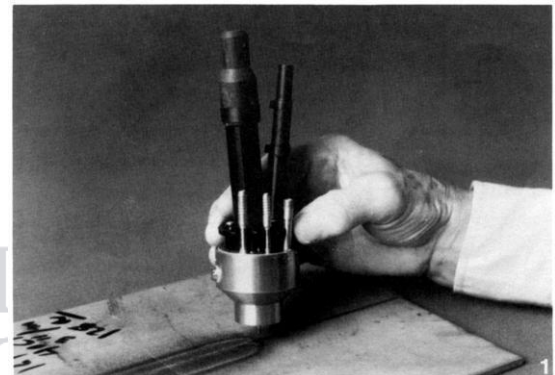


Figure 3: Integrated torch sensor [26]

3 RESULTS AND DISCUSSION

Design and modeling, control system and sensing ability in robotics arc welding focus on vital factors for innovation. Heat transfer, arc characteristics, and weld bead geometry are the important factors that influence the concept in designing welding robot. These factors will directly affect the total cost and power supplies of the whole production. For control system, manufacturers will concentrate more on weld penetration ability, control of joint profile and also control of filling rate. Example presented in this paper is fuzzy logic control, neural network control and knowledge-based control. Seam tracking accuracy is also critical in ensuring high quality product. The same goes to sensor ability. It will depend on how fast a sensor can transform the information from the workpiece, variety of application of the sensor and also covered area of the sensor.

4 CONCLUSION

1. In order to fulfill modern day diversified requirements, significant improvements are needed for each element of arc welding robots. Robots must be able to integrate with their environment in order to produce optimum performance.
2. The ability to present knowledge by using prior information and newly acquired information is another important element. This would provide

people the combination of ideas they have explored.

3. Level of cooperation among robots is also important especially when solving complicated tasks. Working as a team, each part of the robot should communicate well and perform given tasks using best possible solutions.
4. Another issue that should be thrown up into discussion is power supply. Since the world is turning into sustainable way of living, the developed system must be aligned with them. Instead of using electricity, manufacturers could use renewable energy or a closed-loop system which maintain the energy sources. All of mentioned elements will contribute to a major change in technology of arc welding robot.

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