Applications of Robotics in Welding
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Abstract—
An Industrial robot is reprogrammable, automatically controlled, multifunctional manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications. Technical innovations in robotic welding has facilitated manual welding processes in severe working conditions with enormous heat and fumes to be replaced with robotic welding. The robotic welding has greater capability to control robot motion, welding parameters and enhanced wrong detection and wrong correction. Major difficulties in robotic welding are joint edge inspection, weld penetration control, seam tracking of joints, and width or profile measurement of a joint. These problems can be more easily solved by use of sensory feedback signals from weld joint. Robotic welding system has intelligent and effective control system that can track the joint, monitor the joint in process and accounts for variation in joint location. Sensors play an important role in robotic welding systems with adaptive and intelligent control system features that can track the joint, account for variation in joint location and geometry monitor in-process quality of the weld. In this paper various aspects of robotic welding, robot programming, and problems associated with robot welding are undertaken.

Keywords— Robotic welding, sensors, robot programming, phases of welding, hindrances in robotic welding.

I. INTRODUCTION
According to the Robotics Institute of America, a robot is a “reprogrammable, multipurpose manipulator devised to move, materials, tools, parts or specific devices, to variable programmed motions for the execution of various kinds of tasks. With advance in prevailing manufacturing processes, it becomes a new way to realize automatic, robotic, adaptable and innate welding manufacturing. Robot welding is common place in industrial settings, and researchers continue to develop new welding methods and gain greater understanding of weld quality. Mechanized tool and industrial welding have become crucial for industrial welding for mass production because manual welding produces low production rates due to the severe work conditions and extreme physical need [1]. As shown in Figure.1 [2-3] for small/medium production rates robotic production yields best cost per unit performance in comparison to manual and difficult automation. Besides competitive unit costs, robotic welding systems bring other advantages, such as enhanced productivity, safety, weld characteristics, flexibility and workspace utilization, and economized labor cost. With increased applications of robotic welding technology has reduce operator involvement and automated restrains over welding parameters, track of robotic motion, wrong detection, and wrong alterations. Since the level of complication and refinement of the robotic systems is large, their capability to adjust to real time variations in environmental condition are not equal to the capability of human senses to adjust to the weld situations.

Welding forms an essential part of advanced manufacturing and robotic welding is a main symbol of present welding technology [3]. There are three important steps to realize automatic welding similar to welder. The first step is to sense and grab information of the welding process, analogous to human sensing organs for identifying the interior and exterior welding conditions; the second step is to detect characteristics of the welding process, i.e. modeling of the welding dynamic process; the third is to develop the human-brain-like controller to reason controlling actions. A large number of robots are in spot welding, material handling, spray painting and arc welding. Spray painting and Spot welding applications are mostly in the automotive industry. However, arc welding and material handling are used in a broad range of industries, such as, furniture manufacturers, automobile sub-suppliers and agricultural machine manufacturers.
II. ROBOT WELDING

Welding is a fabrication process that joins materials, usually metals or thermoplastics, by causing coalescence. Until the end of the 19th century, the only welding process was forge welding, which has been used from years to join steel and iron by heating and hammering. Oxy-acetylene and Arc welding were the first joining processes that were developed late in the century, and electric resistance welding followed soon after. Robot welding is a relatively new application of robotics, even though robots were first introduced into US industry during 1960s. The use of robots in welding did not take off until the 1980s, when the automotive industry began using robots extensively for spot welding. Typically, a robot welding system consists of a robot, welding equipment, controller, a work clamping devices and motion devices to grasp work pieces precisely in position, robot motion equipments to move round the robot and good weld orientations, sensors, and safety equipments.

A. The Robot

A robot moves the weld torch along the weld path in a programmed direction. A robot consists of a vast number of links and linkages, that are interlinked by gears, chains, belts etc. A large number of industrial robots are driven by linear, hydraulic or pneumatic drivers and/or electric motors. Majority of high end robots are actuated by AC servo motors which have replaced other actuators.

B. Controller

Controller gives signal to the drivers and motors by programmed instructions and location, velocity, and other data received from different sensors. The controller manage not only robot but also any external equipment, such as manipulators. When the system needs to weld a material that has intricate geometry, the synchronized coordinated control of the entire controller is imminent [4].

C. Manipulators/Fixture

A manipulator is a tool that holds work piece and is displaced around for better reach and welding orientation. A manipulator can be moved efficiently hard to reach locations easily. Welding can be done in a flat welding
orientation by an integrating control of a robot and manipulator. A manipulator enlarges the working area of a fixed floor mounted robot.

**D. Welding Torch**

The torch grips the electrode in non-consumable electrode welding, to assure the flow of shielding gas to weld pool and transfer of current to the electrode. Torches with welding current up to 200A are generally gas cooled and for continuous operation between 200 and 500 A are water-cooled. Electrode feed unit and the welding control mechanism in consumable electrode system are usually yielded in one synchronized package.

**E. Shielding Gas Regulator**

The regulator is an equipment that decreases pressure of gas source to a constant operating pressure, irrespective of the change in source pressure. Pressure can be reduced in one or two stages. Shielding gases prevent the weld metal from atmospheric contaminations. Such contamination produce different defects such as porosity, weld cracking, scaling etc. Shielding gases also have a large impact on the stability of the electric arc.

### III. PHASES in WELDING OPERATION

There are three different phases in robotic welding that need critical consideration to achieve best performance and weld quality and are described below:

**A. Preparation Phase**

In preparation phase, the welder keeps together all parts to be welded such as equipments and the weld parameters, along with the type of shielding gas and electrode. When offline programming is used, a robot weld pre-program is available and placed online. Consequently, the robotic program then need only small changes for calibration, which welder operator can do easily by performing preferred online simulations of the process.

**B. Welding Phase:**

Automatic system must have same capacity as manual welding, i.e., the system should be capable of controlling torch position that follows the required path (which may be distinct from planned), performing seam tracking, and changing weld parameters in real time, thus follow the selected behavior of manual welders.

**C. Analysis Phase**

General phase where the welder investigate the weld to ascertain if it is acceptable or whether adjustments are needed in the first two phases. Use of sensors facilitate execution of this phase online during the first phase (welding phase).

All the above three welding phases must be considered while designing a fully automated welding systems to attain best weld quality.

Fig. 3 Robot welding in automobile industries.
IV. ROBOT PROGRAMME TECHNIQUES

There are various modes of programming a robot controller such as manual method, online programming (walk-through, lead-through), offline programming and kinetic teaching.

A. Manual methods

Manual methods are generally used for pick and place robots and are not suitable for robotic welding systems [5].

B. Online programming

This method of robotic programming involves lead-through and walk-through programming. In the walk-through programming, the operator moves the torch manually in the required sequence of movements, which are recorded into the memory for playback during welding. The walk-through programming was used in a few early welding robots [5] but did not prove useful. The conventional way for programming welding robots is online programming with the aid of a teach pendant, i.e., lead-through programming. In this method, the programmer moves the robot to the required orientation by control keys on the teaching pendant and the required orientation and the respective motion sequences are recorded. The main drawback of the online teaching programming is that the programming of the robot causes breaks in production during the programming phase [6].

C. Offline programming

In offline programming (OLP) the programming of weld path and sequence of operations are controlled by computer rather than by the robot itself. OLP uses 3D CAD models of the robots, fixtures and workpieces used in the cell. The 3D CAD models are compared through simulation software allowing programming of the robot’s welding trajectory from a computer in place of a teaching pendant in the welding cell as in online programming. After testing and simulation of the program, the teachings can be conveyed from the computer to the robot controller through an Ethernet communication network. Recent research suggests, however, that the use of sensors, it possible to completely program the final path only with OLP [7].

4.5 Kinetiq Teaching

Kinetiq Teaching is a new technique that assist welder’s knowledge to reduce the programming knowledge needed to teach a task to a robot. Through this add on tool, operators are capable to hand guide the robot and program welding tasks by selecting sequence options via an ICON-based touch screen interface on the teach pendant. With this technique the user physically moves the robotic welding tip next to a work piece. The welder selects the proper procedure through touch screen interface once the welding point is reached. When all the points are registered, the welder can check the programmed path, adjust it as required and go on to weld.

V. NEED FOR SENSORS IN ROBOTIC WELDING

Sensors are mainly used in robot welding to measure the process parameters such as location and geometry of weld pool and online control of welding process. In addition to this sensors are used for inspection of defects in
welding and evaluation of weld quality. For robot welding applications an ideal sensor should measure the weld path should identify in advance seam, corners and should be as small as possible. Generally all the three requirements do not exist in an ideal robot, therefore one should select a sensor suitable for the specific welding situation [8]. Robots with seam tracking capability are equipped with Sensors that can measure geometrical parameters. Technological sensors are used to measure parameters that are mostly used for monitoring or controlling purposes. Contact sensors, like nozzle or finger, are easier to use and less expensive than non-contact sensors. However, contact type sensors cannot be used thin lap joint. Non-contact sensors also known as through-the-arc sensors can be used for tee, U and V grooves, tee joints or lap joints over a limited thickness. Non contact types of sensors are best suitable for welding of large workpieces. with weaving when penetration control is not critical.

VI. ADVANTAGES OF ROBOT WELDING OVER TRADITIONAL WELDING
The main advantages of robot welding system over traditional welding are:

A. Increase in Productivity:
With a robot’s ability to process welded components three to five times faster than humans by operating continuously, withstanding a greater arc on time and moving quickly between weld joint positions, a robotic welding system can provide substantial increases in output.

B. Consistent and Repeatability:
Manual welding requires a high level of skill as well as concentration to achieve consistency and repeatability. A robotic welder can continue to perform precisely the same weld cycle continuously, 24 hours a day, seven days a week.

C. Flexibility:
Manual welding processes require multiple jigs which are swapped out with each production run. Robots can save valuable time and eliminate tool changes as grippers can grab any part regardless of size or shape, position it on the assembly, and hold it tight during the welding process.

D. Safety:
Numerous safety risks exist for welders such as electric shock, exposure to gases and toxic fumes, and welder’s flash burns to the eyes cornea. Robotic welders have proven themselves in reducing the number of accidents to workers in the metal fabrication industry with the number of injuries reported to Safe Work Australia reducing each year.

E. Quality:
A robotic welder can achieve superior quality by ensuring the correct welding angle, speed, and distance with repeatability of accuracy of (+0.04mm). Ensuring that every single welding joint is consistently produced to the highest quality significantly reduces the need for costly rework.

F. Labour:
With a shortage of skilled workers, robotic welders have helped to overcome this issue. Whilst manual welders will still be required for jobs which have a high degree of customisation, a robotic welder will alleviate issues in busy times by reducing additional hours and the need to hire and train extra staff.

G. Reduce Consumables:
With manual welding, the size of the weld is determined from the operator and could result in a larger weld than required. Robots are programmed to always weld to the correct length and size of the joint requirement, providing significant saving over time.

H. Reduced Production Cost:
Through improvements in quality, consistency and productivity a robotic welding system can deliver parts at a reduced cost. Further saving can also be made through reduced energy consumption and consumable costs in addition to lowering workers compensation and insurance costs.
I. Reduction in Weld Distortion:
Weld distortion occurs due to contraction and expansion of the weld metal and near-by parent metal during the cooling and heating cycle of the welding process. Robotic welders are tuned to correctly size the weld for the requirements of the joint, minimise the amount of weld passes and complete the process with speed to minimising the heating of the surrounding metal that can expand and lead to distortion.

J. Increased Competitive Advantage:
Implementing a robotic welding solution can set companies apart from the competition by allowing for faster completion and delivery of products whilst ensuring consistent quality.

VII. HINDERANCES IN ROBOT WELDING SYSTEM
Instead of various advantages of using robotic systems, associated problems need due attention. The main Issues that robotic welding system generally face includes the following:

A. The flexibility needed for making part after part, in lack of proper control, may fluctuate due to improper fixturing or variations in them in metal forming process.
B. The effort and time needed to program a robot to weld a new part is quite high in small to medium manufacturing or in repair work. [9]
C. In case of Robotic welding proper joint design, consistent gap conditions and gap tolerance not exceeding 0.5 to 1 mm are main requirement.
D. Automation of robotic welding systems has high initial cost, so accurate calculation of return on investment (ROI) is essential [10].
E. Need of skilled operators with requisite training and knowledge pose greater limitations to robotic welding system.
F. Irrespective of adaptive nature of human behavior, robots cannot independently make autonomous corrective decisions and have to be supplemented by the use of sensors and a robust control system for decision making.
G. Robotic welding is difficult to perform in some areas like pressure vessels, interior tanks, and ship bodies due to workspace constraints [11].
H. Sensor-based intelligent system available in the market are not flexible with the robot controller, which limits the performance of the robotic system. Consequently, the robot cannot respond quickly to sensor information, resulting inactive and unstable performance.

VIII. FUTURE SCOPE
The automated welding techniques can be used for various numbers of applications. Further, it can be applied to do brazing and soldering applications. A robot can be designed for soldering and brazing applications, which will minimize the human efforts and will increase the accuracy of the product to be soldered and brazed.

IX. CONCLUSION
The advancement in robot technique for welding have provided industry with potent technology that meet almost every requirement. However there are number of problems and complexities associated with robot welding system such as robots are hard to use, limited software interface, difficult to program etc. Nevertheless, robots have significant advantages of producing parts with negligible defects using limited equipment. However robot manufacturers are upgrading robots with higher accuracy, increased reach and low operating cost.

REFERENCES


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