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Robotic Welding Issues and Challenges

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Abstract. *Since industrial robots were first introduced in the early 1960s, robotic welding has seen tremendous advancements and is now one of the most significant applications of industrial robotics. Robotic welding involves the use of automated, programmable machines (commonly called robots) that perform welding operations and handle workpieces without human intervention. These robots are highly adaptable and are employed in various welding processes, including resistance and arc welding. [1] Precision and accuracy are critical in robotic welding systems to produce durable and consistent welds. Manufacturers must carefully calibrate robots to operate within extremely tight tolerances, sometimes as small as a fraction of a millimeter. Such precision is especially vital in industries like automotive manufacturing, where weld quality directly impacts a vehicle's structural strength. Each robotic arm must follow its programmed path with minimal variation to ensure uniform welding results across multiple production cycles and different parts. This article explores the key challenges and issues associated with robotic welding.*

Keywords: Robotic Welding, Industrial Robotics, Welding Robots, Arc Welding, Robotics, Welding

1. Introduction

The welding process was discovered in the beginning of the last century. The traditional manual welding has low efficiency and poor accuracy. Moreover, the manual work is not only time - consuming and laborious, but also high - intensity. Sometimes the workers even have to face poisonous and dangerous environments. [1] But the robotic welding is complicated process and also needs high qualified manual work. Recently, the industrial welding robots are gradually being appreciated and widely used in the industrial producing to replace manual producing due to their advantages like high accuracy, persistent work, and fitness for complex environments. [4] The welding robots have already been widely used in industrial producing, especially in the fields that require high welding accuracy like aerospace and precise instruments, and are gradually replacing manual welding. [6].

2. Welding automation by robots

Welding automation by robots usually is performed by rectilinear or articulating robots. The simple ones are rectilinear or cartesian robots that use links moving in line in any of three axes (X, Y, and Z). In addition to linear movement of the robot along axes there is a wrist attached to the robot to allow rotational movement. This creates a Cartesian robotic working zone. Articulating robots on the other side utilize links with only rotating joints. These robots move like a human arm with a rotating wrist at the end. This creates an irregularly shaped robotic working zone known as the work envelope. In general equipment for automatic arc welding is designed differently from that used for manual arc welding. Automatic arc welding normally involves high duty cycles, and the welding equipment must able to operate under those conditions. In addition, the equipment components must have the necessary features and controls to interface with the control system. The number of items of any one type to be welded must be high enough to justify automating the process. If the joints are to be welded on a work piece are few, straight and easily accessible, a rack automatic gas metal gas welding (GMAW) gun or gas tungsten arc welding (GTAW) torch may be suitable for key welds. An automatics gun also can be used in a fixed position or on a curved track for a curved or circular weld such as joining two pieces of pipes or welding a flat base to a cylindrical shape - a task in which a work piece can be rotated past the gun. If parts are normally need adjustment to fit together correctly, or if joints are to be welded, they are too wide or different positions from piece to piece, automating the procedure will be difficult or impossible. [4] To maximize effect - welding work piece there are additional orientation axis modules called positioner. At the positioners parts can be revolved to allow access to 5 sides of welding. Robots work well for repetitive tasks 11 on similar pieces that involve welds in more than one axis or where access to the piece is difficult. Welding robots are used in two ways in manufacturing – as elements in production line and as stand-alone units for batch production. Few companies move from all manual welding to a completely automated production line, so many people introduce robotic welding with a standalone cell. At fabrication or welding trade shows, a variety of welding robots can be seen performing complex maneuvers and elegant pirouettes similar to troupe ballet dancers. These displays are designed to demonstrate the speed and flexibility of today’s generation of robots. The fact is, dance moves aside, today’s robots can handle a wide range of welding applications. [4]

Some of the welding operations that can be performed by robots are as follows:
1. Arc welding
2. MIG welding
3. TIG welding
4. Spot welding
5. Stick welding

Industrial Robotic Welding is by far the most popular application of robotics worldwide. In fact, there are a huge number of products that require welding operations in their assembly processes. The car industry is probably the most important example, with the spot and MIG/MAG welding operations in the car body workshops of the assembly lines. Nevertheless, there are an increasing number of smaller businesses, client oriented, manufacturing small series or unique products designed for each client. These users require a good and highly automated welding process in a way to respond to client needs in time and with high quality. It is for these 7 companies that the concepts of Agile Production apply the most, obviously supported by flexible manufacturing setups (Figure 1). Despite all this interest, industrial robotic welding evolved slightly and is far from being a solved technological process, at least in a general way. The welding process is complex, difficult to parameterize and to effectively monitor and control. In fact, most of the welding techniques are not fully understood, namely the effects on the welding joints, and are used based on empirical models obtained by experience under specific conditions. The effects of the welding process on the welded surfaces are currently not fully known. Welding can in most case (i.e. MIG/MAG welding) impose extremely high temperatures concentrated in small zones. Physically, that makes the material experience extremely high and localized thermal expansion and contraction cycles, which introduce changes in the materials that may affect its mechanical behavior along with plastic deformation [4].

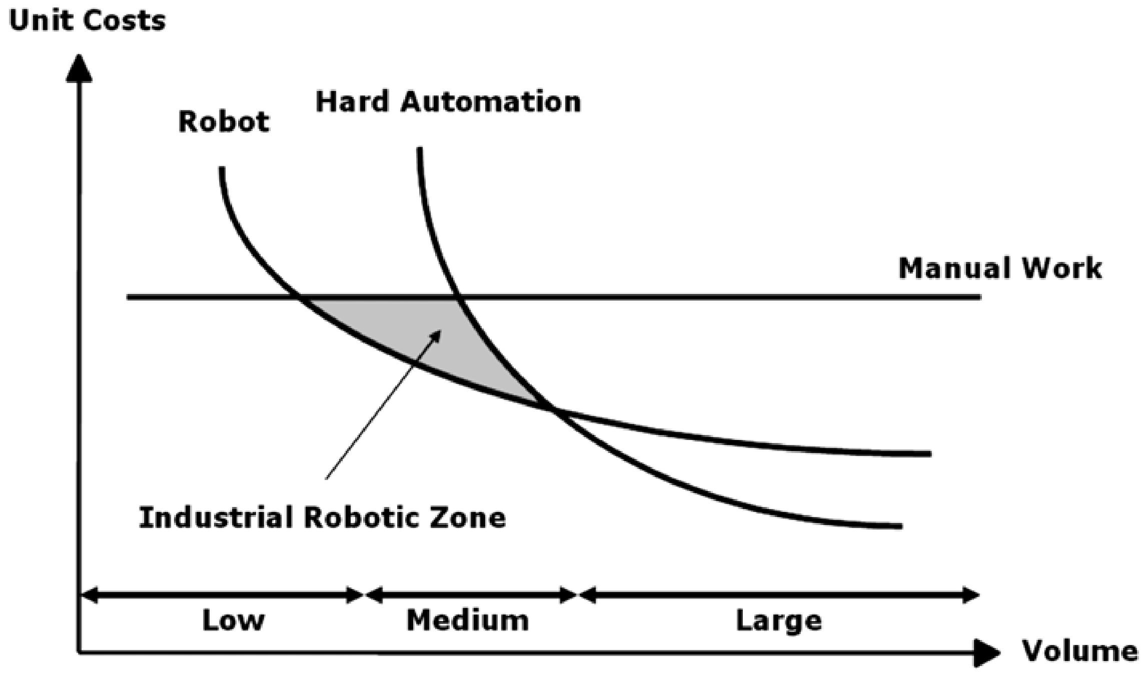

Figure 1. Industrial robot zone [4]

Those changes must be well known in order to minimize the effects. Using robots with welding tasks is not straightforward and has been a subject of various R&D efforts. [4] And that is so because the modern world produces a huge variety of products that use welding to assemble some of their parts (Figure 2). If the percentage of welding connections incorporated in the product is big enough, then some kind of automation should be used to perform the welding task. This should lead to cheaper products since productivity and quality can be increased, and production costs and manpower can be decreased. Nevertheless, when a robot is added to a welding setup the problems increase in number and in complexity. Robots are still difficult to use and program by regular operators, have limited remote facilities and programming environments, and are controlled using closed systems and limited software interfaces [4].

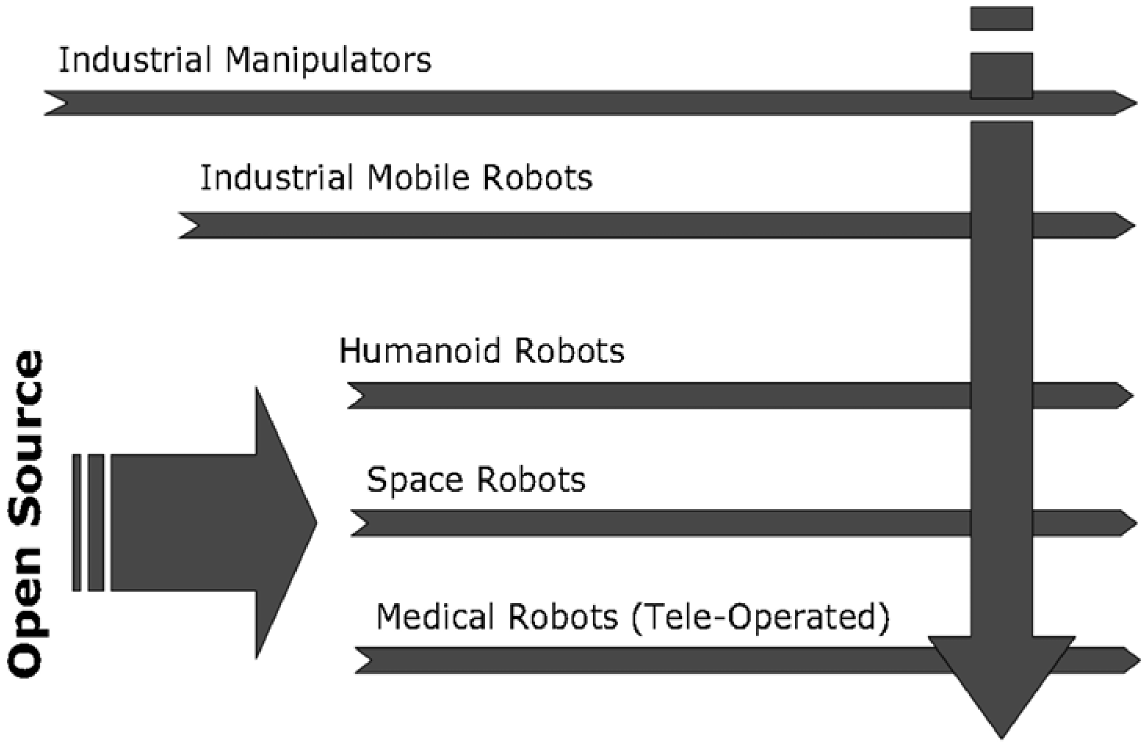

Figure 2. Traditional and modern fields in robotics research [4]

2.1. Welding Challenges

There are many factors that need to be considered when setting up a robotic welding facility. Robotic welding needs to be engineered differently than manual welding. Some of the considerations for a robotic welding facility are listed below: The selected welding programs include start / stop, gas pre flushing, electrode feed and nozzle flushing. [5]

At the MIG/MAG welding process, also known as gas metal arc welding process uses the heat of the electric arc to melt the electrode wire and the metallic components to be welded. Figure 3 illustrates the welding process. The fusion is carried out under the protection of a gas, or mixture of gases, in order to prevent pernicious contamination with atmospheric gases (oxygen, nitrogen, and hydrogen). [5]

Figure 3. Welding process

The stability of the welding process is sensitive to basic welding parameters, especially current, voltage, welding speed, stick-out (length of wire out of the contact tube), shielding gas, and arc length. A small change in the distance between the welding torch and the component being welded may produce a considerable variation on current and voltage. Current, voltage, and shielding gas influence the transfer mode of melted filler wire to the component being welded, affecting the quality of the welds. If the electric arc is unstable, defects, like bad penetration profile, undercut, or excessive spatter, may occur. [2]

As the weld bead shape may be closely related with the welding parameters, MIG/MAG welding process databases have been developed, such as the one at the Welding Institute in the United Kingdom. In these databases, the input data is generally the type of weld (butt or fillet), the welding position (flat, horizontal, vertical, or overhead), wire diameter, and plate thickness or, eventually, the leg length in the case of fillet welds. The output data is usually the welding parameters (current, voltage, welding speed, and number of weld beads/layers).With databases of this type in the computer, the selection of the welding parameters may be made automatically. Even the selection of the wire diameter may be carried out automatically as a function of the thickness of the components or remain an input parameter. [2]

It would be expected that, having a CAD model of the component to be welded, the system would be able to select the welding data for each weld and send their data to the robotic welding system. Though it seems easy to achieve this goal in the case of single welds, some data is missing in the data base in the case of welds with multiple layers. In this case, in fact, the position of the torch in each layer needs to be indicated to the robot. [3]

For the majority of the companies that produce multilayer welds, there are only a small number of distinct welds, so it is not hard to fill up the database for their particular case. [3]

With this method it is easy to carry out the offline programming of the components to be welded; it is only necessary to adjust the coordinates of the process points in the first specimen to be welded [3].

The main and biggest problems are the implementation of the created computer models. Implementing and obtaining the closest reality to the computer model creates numerous difficulties in physical reality, examples of which are maintaining the trajectory of the weld and obtaining an uneven relief of the weld.

2.2. Advantages of welding robots

- Higher efficiency: Robots can work continuously without taking breaks or getting tired, leading to faster and more efficient welding. This can result in increased productivity and cost savings for businesses.
- Higher consistency: Robots can perform the same welding task repeatedly with the same level of accuracy, leading to consistent results. This can lead to higher quality welds and fewer defects.
- Safer: Robots can be programmed to work in hazardous environments or areas that are difficult for human welders to access. This leads to increased safety for workers and a reduction in workplace accidents.
- Higher quality: Robotic welding produces high-quality welds with minimal defects. This can lead to better product quality and a reduction in the number of rejected products.
- Increased output: Robots can work faster than humans, without any loss of accuracy, and they do not fatigue or need to take breaks. This allows for greater throughput and productivity [5].

2.3. Disadvantages of welding robots

Despite the advantages of using a robotic welder, they also present a few concerns. Robotic welders are expensive to purchase, which means that an average business cannot afford one. They require trained personnel to man and program and can often break down or need repair. Other concerns are that the limited movement of a robotic arm might not allow the robot to weld all necessary places. This means that a human welder will still have to go in and finish the job. If the object needing to be welded has been placed incorrectly, the welding robot will still weld in exactly the same programmed places, so that the welds are "off" or located in the wrong place. [4] Poor programming can also produce inaccurate results. Robots are also limited to only a few types of welding, and many of these take longer to cool or can even weaken metal if not used properly [4].

- Higher start-up costs: Robotic welding necessitates the acquisition of robots and the training of robot operators. The cost of doing so may be too high since the welding jobs you may be having are few. Hence, outsourcing for the robotic welding service could be the most ideal cost-saving act.
- Less flexibility: Robots are not as flexible as humans and may not be able to handle different weld types. This can limit the range of welding tasks that can be performed by robots.
- Inability to make decisions: Robots are not able to make decisions about certain procedures if necessary data is missing.
- Not suitable for smaller projects: For smaller projects, it may be easier, cheaper, and far less stressful for a manual welder to undertake jobs. Incorporating robotic automation processes into smaller projects could mean that the programming time actually takes longer than the welding job itself, and this would be counterproductive.
- Limited functions: The functions of robots can be limited, especially if you are using specialized robotics for processes such as welding. The designated process may be efficient, but some robots are unable to perform certain processes, making them inefficient [5].

3. Conclusion

In summary, robotic welding is a transformative advancement that is reshaping manufacturing, delivering exceptional efficiency and productivity - especially in high-volume operations. Its key benefits include consistent weld quality, higher production rates, less material waste, and decreased labor expenses. However, there are important factors to weigh, such as the substantial upfront costs, limited suitability for smaller-scale work, reduced flexibility, continuous maintenance needs, technical complexities, and constrained versatility.

Despite these drawbacks, skilled welders remain indispensable for detailed or specialized jobs, offering adaptability and craftsmanship that robots cannot yet match. Highly qualified personnel are also needed to program the robots. The best approach combines the strengths of both robotic welding and human expertise. Robots perform best in repetitive, precision-driven tasks, while human welders provide critical problem - solving skills for complex welds and unique project demands. By integrating robotic automation with skilled labor, manufacturers can achieve an optimal balance, enhancing productivity, quality, and adaptability in welding operations. Despite the challenges, they are solvable and the trend is for robotic welding to increase its share in practice.

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