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Welding using Advanced Robotics

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Abstract: ***The Robotic welding has been able to replace physical welding in hostile conditions with extreme temperature and gas vapors because now sensor-based features are available for controlling the robots in welding processes which is a great tech. advancement. The industrial robots are mainly used in the GMAW which gas metal arc welding and in high-capacity productions. Greater capability to manage welding settings and robotic movements, as well as enhanced problem identification and repair, have been necessary as robotic welding has become more widely used. The requirement to adjust for imperfections in work piece fixtures, fluctuations in dimensions of work piece, improper preparation of edge, and thermal distortions etc. issues that semi-automatic robotic welding (needing very minimum human interaction) encounters. Seam tracking and detection of edge of joint, controlling penetration of weld and measuring joint dimensions are some major issues. To tackle these challenges the best way is to use the sensors and take the feedback signals from the weld joint .Therefore, from evaluating underway weld quality, variation in shape & position of joint to tracking of joint, sensors play a vital role . This paper discusses robotic welding in general, robotic welding system programming, and robotic welding difficulties. This research expands knowledge of robotic welding, the importance of sensors in the welding process by the robots, and the issues that come with it.***

Keywords: Welding, robotics, sensors

1. Introduction

1.1. Background

Robotic welding made its debut in the practical world in 1962. The Unimation 001, a robot created by George Devol and Joseph Engel berger, was installed at a General Motors facility to do spot welding on an assembly line, a technique that was deemed dangerous for humans. However, robotic welding did not gain popularity until the 1980s, mostly in the car manufacturing business. Other automakers realized the benefits of welding automation that GM had experienced and began using robotic spot-welding methods in their own plants. Robotic welding began to make inroads into other areas, such as metals manufacturing, as the benefits of welding automation became more widely acknowledged. Robots are now more functional and productive than ever before because to recent advancements such as sophisticated motion control and 3D laser vision. Manufacturing organizations are being forced to hunt for optimal production techniques as a result of volatile market behavior and fierce competition. The welding done by robots delivers the best cost/item ratio as compared to the hard automation and physical welding.

1.2. Robotics welding advantages

Since the first spot welding robot in 1962, robotic welding methods have come a long way. Manufacturers are recognizing the benefits of robotic welding across a wide range of industries in order to stay competitive in an ever expanding and highly competitive global economy. One of Since the first spot welding robot in 1962, robotic welding methods have come a long way. Manufacturers are recognizing the benefits of robotic welding across. A wide of industries in order to stay competitive in an ever expanding and highly competitive global economy One of the most significant advantages of robotic welding are as follows. Quality: The quality of welding done by robots is very high and precise. They can also duplicate these welds with the same level of precision as a result, welding is constant and trustworthy. Productivity: On an assembly line, robots increase productivity. They can do complex simultaneous welds, work quickly without losing quality, have consistent repeatability, and work tirelessly. Robotic welding speeds up production and provides a considerable return on investment in the long run. Safety: Humans performed all welding procedures until around seventy years ago. They were exposed to dangerous conditions and vapors as a result of this. Welding is no longer dangerous because of robotic welding. Robots are assisting producers in meeting the novel needs of a changing competitive landscape by improving the quality and repeatability of dangerous and intricate welds, as well as lowering costs and increasing production. Robotic welding has opened up new possibilities in non-traditional applications thanks to powerful new robots.

1.3. Introduction to problem being addressed

Now, with great advancements there comes some major challenges of the robotic welding in today's world and we are going to address these challenges and problems in this report. We will also discuss some solutions to overcomes these problems. We discussed about all the benefits of robotic welding. Though these robots are very powerful and complex, their potential to adapt to real time changes cannot be compared to the ability of humans especially in the ambient conditions. The flexibility of human senses to adjust to welding environment is robot by analyzing the situation and the parameters like identification of fault, correction of fault and robotic motion path. This dependency on the user unmatchable. There requires some operator who modifies the input needs to be decreased to make the robots more automated. This dependency on the user input needs to be decreased to make the robots more automated. Hence, this inflexibility of the robotic welding brings major challenges like joint seam tracking, joint weld detection, dimensioning of the joint profile and at last, weld penetration control. The utilization of feedback signals from the weld joint is the most effective way to tackle such challenges. And these feedback signals can be generated by the sensors.

1.4. Overview of the topic

"Sensors in robotic arc welding and programming in industrial applications". From evaluating underway weld quality, variation in shape & position of joint to tracking of joint, sensors play a vital role. We'll go over many parts of robotic welding. We will talk about the robotic system programming and the issues related to the programming This report expands knowledge of robotic welding and the importance of sensors in robotic welding, as well as the issues that come with it.

2. Literature Survey

2.1 Welding seam tracking technology

The location and configuration of the weld changes as a result of machining and assembly faults, as well as weld deformation due to uneven temperature fields. In order to alter the weld, the technology of seam tracking is utilized to see the welding state in real time during the process. To assure the quality of the weld, the path is crucial [3]-[5]. Weld seam tracking technique currently relies primarily on sensor and control technology. Sensor applications are evolving in the welding robot industry, from single sensors to multisensory intelligent information fusion. Hybrid and fuzzy approaches of control are widely used to study seam of the weld monitoring method in terms of control. The technology of tracking of seam weld gains stronger command qualities, such as flexibility and self-learning, as a result of their combination.

X. Li, M. O. Khyam conducted research on "Robust welding seam tracking and recognition" [2].They provided a robust solution to the welding seam tracking as they approached the welding seam placement problem as a visual aim tracking. Figure 1 depicts the weld seam tracking system. The technique of this method is discussed. First, the seam is distinguished by taking help of accumulating gray frequency. It is done before the start of the welding. The collected information is used to flexibly find the starting size and location of the search window. They also proposed a second method to get a better-quality output of the seam's mid-line. It helps to decrease the effect of noise (which generates due to the intersection of noise with seam) on the precision of point placement. This method was called sequence gravity method. The curve obtained from this method was then fitted using the "double-threshold recursive least square method" which helped in real time enhanced precision and performance of the process. Thorough experiments were then performed to compare this method with other different seam finding methods. This method turned out to be best of all. S. Gu and Y. Shi also did relatable research which was based on TIG welding [6]. They suggested a novel type of deep penetration TIG welding with weld deviation identification. Figure 2 depicts the principle. To begin, they employ a bilateral filter to reduce noise from images captured with a high dynamic range CCD while preserving the edge of the region of interest. Second, to get precise arc shape of welding, weld properties, and weld pool, the revised Otsu algorithm is applied. Then, to obtain a complete edge contour, they offer the canny algorithm. Finally, the greatest curvature algorithm and parabolic are used to produce the pixel coordinates of the weld's midpoint and the arc center line, respectively.

Experiments were performed thoroughly and the results obtained were quite satisfying. The coordinates of seam and the fluctuation of center line of arc were precisely determined by this method. The obtained results can then be used to correct and modify the program in real time and hence the precision of the robotic welding improved.

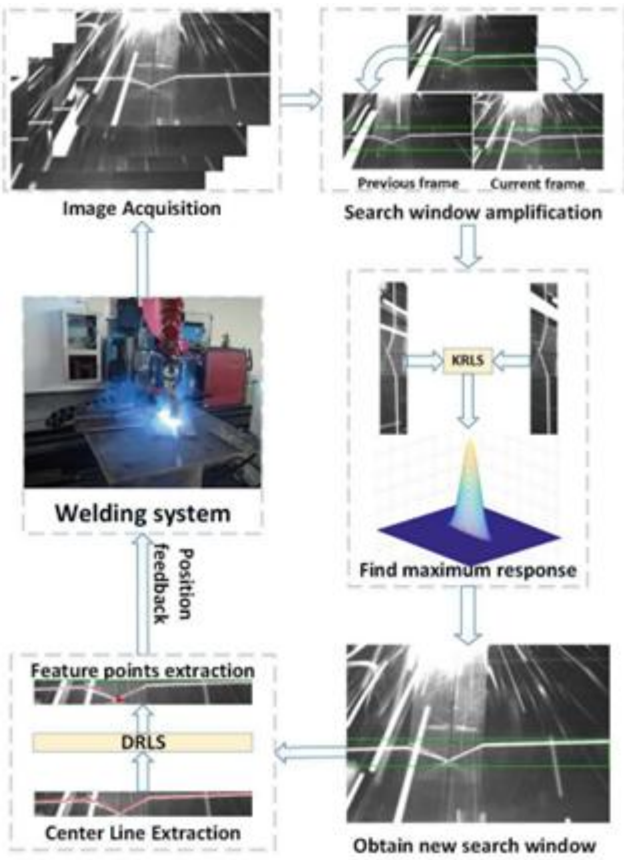

Figure 1: Welding Seam Tracking System

2.2 Summary of literature survey 1

According to the literature cited above, significant progress is achieved in the research of seam monitoring tech. The system's further development tendency is to incorporate modern tech. such that it gets higher valuable information for tracking method and therefore, boost its intelligence. The image-based seam tracking method, on the other hand, is difficult to process due to the vast volume of picture data, and there is a lot of work to be done. We need to investigate how to find the simplest and sophisticated method to achieve a quality outcome.

Figure 2: Robotic Tig Welding

2.3 Off-line programming technology

Currently, the programming methods of welding employed in the field of production of robot welding is mostly instructional programming, that poses a number of safety concerns for both programmers and welding robots. Simultaneously, welding product manufacture is evolving toward flexible manufacturing, which includes multi-variety, small-volume, and complex flexible manufacturing. Extreme conditions, like nuclear power, space and deep down in water are all part of welding programming workspace. These reasons make teaching programming difficult to implement. The following challenges can be effectively solved by implementing off-line programming and simulation technology.

H. Shen did study on off-line programming in 2017[6], based on the secondary development function of the 3D software UG, a 3D visual off-line programming system for a six DOF robot was developed (Figure. 3). It accomplishes the functions of modelling the system, status monitoring, planning the path, simulating motion, and off line programming, using C++ language and development and functional tools. The solution can meet the six- DOF robot's off-line programming needs in the welding of the doors of vehicle.

2.4. Summary of literature review 2

According to the preceding literature, specialists in off-line programming and simulation technologies are quite advanced. But there are some disadvantages of this method in some nations because of non-open source code of programs and high prices of programming. On the other side, it is strongly reliant on UG, SolidWorks, and other 3-D software produced in China. They take long time & costs a lot of money to run in practice.

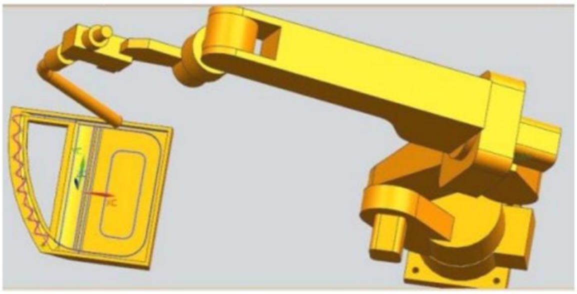

Figure 3: Welding robot motion simulation

3. Problem Definition

Till now, we have discussed about the importance of robotic welding in modern welding technology. The robotic welding systems have evolved and came a long way. The upgradation of any system is only possible when there is urge to make the system more advanced, reliable, flexible and efficient. Same is the case with robotic welding, in the first-generation systems two pass method was followed where first pass learns the geometry of seam and then second pass does weld work. Then there comes advancements which leads to second generation systems, where two passes were combined to single pass and both the work of two passes was done in single pass about which we have discussed in the literature review section. But we saw some limitations and issues with this system too. The system is not so efficient as it needs to process lots of data and a lot of work is to be done to modify this process. We need to boost the intelligence of the robot and make it to learn on itself, so that it quickly adapts itself to the seam geometry in an unstructured environment where the welding location and welding curve is not fixed. Hence this is our motivation behind the work and to bring the third-generation systems.

The objectives of the current work is to bring up the issues in the current generation robotic welding systems, how they affect the results and what improvements can be made to improve the results. We will see the importance of sensors in rectifying the current problems in the robotic welding systems and their vital role in bringing flexibility to the systems. One more objective of the work is to show and proof the progress made by incorporating the sensors in robotic welding system.

4. Methodology

4.1 Approach

First, we will see a typical welding robot and its configurations. Then we will discuss about the critical phases of the welding which needs our attention and consideration while designing a robot for welding purpose which is completely self-operating, so that we can attain high grade welding system with great performance. In each phase, we will first discuss the manual method of that particular phase and then discuss about the automated method and compare both of them. Then, we will discuss about some more problems in robotic welding and discuss on the need of sensors in this system. We will then discuss on different categories on sensors based on operation time, type of sensor, their advantages and drawback. We will then see some of the most vital sensors used in welding operations. Finally, we will discuss on the results obtained and conclude the work with a brief conclusion of the report.

4.2. Robotic Configurations

The robots can be classified based on:
1) The technology that governs and drives the robot
2) The geometry of the workspace of robot
3) The motion feature of the robot
4) Kinematic design and DOF of the robot.

All of these characteristics must be addressed while selecting robots for a certain application. In Robotic arc welding at industrial level , robots with revolute layout are the widely utilized variety based on geometry of workspace of robot . Figure 4 shows an example of a robot with a jointed arm configuration.

Figure 4: A robot with revolute configuration. It has 5 arm joints

All three major steps of welding process:
1) Preparation Phase- First the machine worker arranges the parts properly, which are going to be welded. Then he/she sets up all the apparatus like the program of the robot, robot itself and the source of the power, the electrode wires to be used and the gas which is to be used. Then he/she sets up the parameters of the welding operation. Then, offline programming like CAD is used and a pre-program is accessed and putted online. . As a result, the robotic welding may only require minor calibration tweaking, which the welder operator may readily accomplish by running a online simulation of process chosen.
2) Welding Phase- Automatic welding apparatus must have equal abilities as physical welding apparatus, such as ability to maintain the orientation of torch that follows the trajectory as desired (it may be different from pre-decided trajectory), perform tracking of seam, and change parameters of weld in real time, simulating the flexible nature of physical non automatic welders
3) Analysis Phase- It is a post welding phase in which the operator studies completed work to see is it satisfactory or if any adjustments to the previous two phases are required. This step is completed online simultaneously with welding phase thanks to modern sensors like 3D laser cameras.

4.3 Issues in current robotic welding systems

Despite the benefits of adopting robotic welding, several problems are there that must be addressed. The following are some of the issues. The time and work required to programme the robot to weld a new item in low to medium production volume or maintenance activity can be rather large. Robotic welding necessitates correct joint design, stable gap conditions, and a gap tolerance of 0.5 to 1 millimeter. Gap filling involves the employment of sensing technologies due to variations in gap condition. Operating robots require skilled workers and their shortage is also a major issue. Robots are not flexible like humans. Human welders take decisions and modify process according to the current instant situation but robots can’t. But they can do it we modify the robots with sensors and a control system that is robust. Robots don’t have complete control over the process and they are pre-programmed to a certain set of conditions. If a novel situation arises like a fluctuation due to bad fixturing or there is some unknown variation in metal forming process the robot will not be able to understand it and hence do incorrect welding. It can be modified with use of Machine learning and artificial intelligence. Both these techniques require huge amount of data from the welding operation which is only possible using sensors and then exporting required data from it. From the problems only, we see that there is a very high and urgent need of advance sensors in robotic welding process.

5. Results and Discussions

At the moment, welding robots are mostly used in automated production processes, with the majority of them employing playback & teach robots that needs a lot of practice There will be time for practice and planning of path, among other things. Moreover, If the instruction & programming are not successful, they are performed again. As the dimensions of workpiece vary, so do the dimensions of the weld workpieces. During the welding process, it is unable to self-correct. The location of the seams, in particular, is frequently altered in practice due to a variety of issues. The usage of sensors is a good idea, a technique to deal with these issues in automated robotics procedures for welding. Sensors are primarily used to identify and monitor in-process characteristics and parameters such as geometry of joint , position and shape of weld pool, and welding process controlled online. Sensors are also utilized for weld fault inspection and quality assessment. The optimal sensor measures the point at which welding needs to be done (to minimize misalignment of track), identify ahead of time (to determine the seam's start point, recognize corners, and avoid collisions), and be as tiny as feasible so that there is no restriction in accessing. There are no perfect sensors that meet all three characteristics; consequently, one must choose a sensor that is appropriate for the specific welding project. Sensors that measure geometrical characteristics are primarily used to give seam-tracking and/or search capabilities to the robot, allowing the robot's path to be adjusted in response to geometrical deviations from the nominal path. Technological sensors are employed to monitor and/or regulate factors inside the welding process in order to ensure its stability.

Robotic welding uses some vital and most used sensors which are discussed below:

1) Seam Tracking Sensors: This sensor is used to rectify and avoid the changes in seam which happens due to improper heat transport, changes in gap size etc. It does so because it makes the welding torch to impulsively follow grove of weld seam and modify the robotic manipulator as needed. Some benefits of good seam tracking sensor is that it corrects itself in both direction when needed, it adapts itself according to parameters of welding, the time of programming is reduces, the quality of weld is improved.

2) Seam Finding Sensors: This sensor ensures that the weld material is properly deposited at joint location. The technology used in this sensor is that it first finds the seam by doing couple of searches. It then regulates the manipulator and torch to correct location & orientation. Some industries like automotive does not require this sensor because they do small but repetitive welds. But in most of the industries this type of sensor is needed to find the correct weld location.

3) Adaptive Control Sensor System:A process control system detects changes in welding conditions automatically with the assistance of sensors and guides the equipment to take necessary action in adaptive control welding, which is a closed loop system employing feedback-sensing devices and adaptive control. In adaptive control welding, sensors are required to locate the junction, measure root penetration, perform bead placement and seam tracking, and assure correct joint fill. Sensors enable for adaptive control and modification of process parameters such as welding current and voltage in real time. Sensors' skills in seam detecting, identifying joint penetration and joint filling, and assuring root penetration and suitable weld bead shape, for example, allow for corrective change of pertinent welding parameters to ensure consistent weld quality. An adaptive welding robot should be able to deal with two major issues. The first element is controlling the end effector's route and position so that the robot can precisely track the joint to be welded. The second is the real-time control of variables of process like controlling the amount of weld material which is depositing in the joint. The flow chart of adaptive control of parameters of welding system is shown in Figure 5.

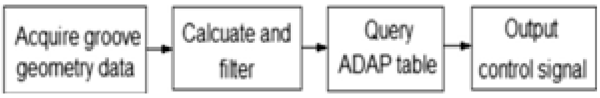

Figure 5: Parameter of adaptive control in weld system

4.) Quality Control Sensor System: Because less staff is required for inspection, the use of automated weld quality monitoring systems lowers production costs. Weld flaws such as porosity, metal spatter, uneven bead form, excessive root reinforcement, incomplete penetrations, and burn-through should be classified by an autonomous detection system for welding. The majority of commercial monitoring systems operate in the same way: voltage, current, and other process signals are monitored and compared to nominal levels. When the difference between the preset values surpasses a certain limit, an alert is triggered. Limit is taken in sync with the actual weld defects. Before the use of sensors in quality control some other methods were used that didn't harm the part. Some methods are acoustic measurement, radiography, eddy current calculation etc.

Figure 6 displays an example of a weld inspection sensor for evaluating weld quality and misalignment of welds during cooling based on a scanning thermal profile called ThermoProfilScanner (TPS) from HKS Prozesstechnik GmbH [10]. TPS can identify seam irregularities such as inadequate weld penetration, weld seam offset, holes, absence of fusion, and so on because the thermal profile (symmetry, breadth of a thermal zone, maximum temperature, etc.) and the seam quality are closely associated. To compare the target values and tolerances, past experience with correlations between thermal profile and weld quality can be employed. As the threshold is reached the process is stopped. The defective locations are marked.

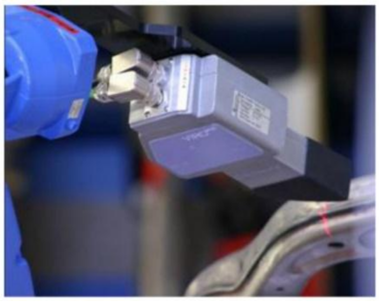

Figure 6: Seam examination by VIRO

To calculate a point cloud in 3D, the parallel structure takes 35% fewer arithmetic operations, making it more suitable for practical applications. Researches have shown that technology can scan huge surfaces range, which also includes the necessary metal components for welding with robots. Using this way, the robots may adapt route from CAD models into real working parts. It is also feasible to create the route online by making use of scanned area for non-recursive activities and if there is unavailability of CAD model.

6. Conclusion

In industrial manufacturing, robotics and sensors, as well as the control systems that go with them, have become critical. They provide a number of benefits, including enhanced quality of welding, higher production, lower cost of welding, greater welding uniformity, and decreased input from humans for weld parameter choice, motion path of robot, repair and detection of fault. We have addressed the problem of inflexibility of robotic welding which leads to several problems like inconsistency, lack of proper design, high programming, inability to detect joint and inability to control the welding parameters. We then successfully discussed on the solution of these problems that is to use advanced sensors to modify the process by instant current situation by evaluating the process parameters. The data obtained from these sensors can be used to learn the machine by the machine learning technology and artificial intelligence technology so that if a similar situation arises in future the robot make use of the past result and modify that to give better output and results.

We also saw the technology of the vision sensors and how they make use of artificial intelligence to detect the seam from the images obtained instantly which then modifies the welding parameters like torch length robot position and configuration to weld at proper place and deposited required amount of welding material. With all these advances we can state that the sensor robotic welding has entered into the third-generation systems. With lot of benefits and advancements in field of sensor based robotic welding there are still some issues with it which needs to be addressed and corrected in the near future to get better output quality and efficiency. Robotic welding uses a range of sensors to measure and identify numerous techniques characteristics and parameters, like geometry of joint, shape of weld pool, position, and so on, as well as to manage the weld process in real time. Seam detection, tracking of seam, adaptive control, monitoring of weld grade are key goals of these sensors, in conjunction with the control system.

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