

Methodology for Human Robot Interface in Arc Welding Operation - An Industry Case study

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Abstract— Welding is a significant industrial application that has been implemented since the early 18th century. The introduction of welding robots in the 19th century resulted in drastic improvements in the field of welding like improving the accuracy of welding, quality of the weld, etc., However, there is no literature which briefs the industry methodology to interface HMI with the industrial robots. In this paper, MOTOMAN AR1440 Industrial Welding Robot is interfaced with the Human Machine Interface (HMI) panel to improve the communication between the machine and the operator. This improves the safety and handling of the robot. The robot trajectory is taught using a teach pendant and the HMI panel is designed to control the robot. The robot and the HMI panel are interfaced via Ethernet communication. Thus, the main objective of this paper is to brief an industry methodology to interface an AR1440 robot with an HMI panel for arc welding application thereby, improving the communication between the machine and the worker.

Keywords— Human Machine Interface, MOTOMAN AR1440 robot, Robotic welding, Pendant programming.

1. Introduction

Welding is a process that involves joining two or more metal parts together. It consists of two parts namely, the base metal and filler metal. This research paper involves the MIG (Metal Inert Gas) type of arc welding operation, the basic principle of this type of welding is the generation of heat in the form of the electric arc due to the contact between the wire electrode and the workpiece. Shielding gas like Argon or carbon-dioxide is used to prevent contamination of the workpiece due to external environmental conditions. In this paper, the MOTOMAN AR1440 robot is used to perform the arc welding operation. The robot is interfaced to the Human Machine Interface (HMI) panel via Ethernet. Of the different welding techniques, we have used the short-circuit welding technique, where the wire electrode is supplied with a positive charge and the workpiece mounted on the welding table is grounded. When they come into contact with each other an electric arc is produced which starts the arc welding.

2. Related Work

This section involves the analysis of different research done previously related to robotic welding and improvements in

the welding operation. [1] speaks about multi-robot welding along with their features like seam welding, offline simulation, remote control, etc., [2] stated on improving the accuracy of the robots during the repetitive process using the B-spline trajectory algorithm. This algorithm is further enhanced by using an RC-type mechanism which will modify the real-time control points to nullify the tracking error. [3] speaks about the integration of hardware and software in interfacing HMI to a wheelchair to minimize human intervention using an intelligent control algorithm. [4] stated that interfacing industrial welding robots with sensors will reduce the problems faced during the welding operation. Some of the problems faced during welding are improper fixing of the workpiece, which may result in irregular beading, inaccurate workpiece dimension, irregular edges, etc., Hence, by using sensors we can eliminate these problems to a great extent and improve the overall quality. Sensors will send feedback, thus enabling us to rectify the problem. [5] stated the development of a cognitive information communication method to provide remote support to the industrial robots using the Human-machine Interface. [6] speaks about the development of a welding robot interfaced with a sensor for the butt-welding operation. [7] stated on bringing ease to the industrial workers when faced with complex welding operations like multilayer welding and multipoint welding. In multilayer welding, the welding parameter is adjusted to perform the welding and in multipoint welding, the CAD diagram is processed and the weld points are taken. Now for these points, different trajectories are designed using the weld panel. [8] speaks about optimizing the energy consumption using the MIG welding process thus, resulting in low carbon emission. [9] stated the basic methods for measuring current and voltage parameters to improve the weld bead quality. [10] stated about the design and implementation of an intelligent seam tracker system that can operate without preprogramming in real-time in an unstructured environment. Current and Voltage settings are important parameters in the welding process, reference for fixing such parameters for shielded metal arc welding is analyzed in [11]. [12] speaks about improving the steering variable responsible for stabilizing the

welding process using techniques like dimensionality reduction and Vector Support Machine for autonomous robotic welding. [13] stated that individual ideas are involved in industry 4.0 and its implementation in welding technology. [14] stated that manual welding is not suited for complex workpieces, introducing robotic welding will help the workers in welding complex workpieces as well as increases the efficiency of production rate. [15] speaks about the various recent advancements done in robotic welding and its application to reduce capital investment and increase the production rate. [16] speaks about designing intelligent robots by interfacing the robot with sensors. [17] stated that robots are needed for welding purposes since rework of defective workpieces is expensive in manual welding. The Jacobian controlling algorithm is used for designing the welding robot. [18] stated that by using the inverse kinematic solution, the welding robot movements like weld joint and weld torch movements are controlled by optimizing the weld parameters. [19] shows the instructions for building the ladder editor in the teach pendant of the YRC1000 controller. [20] shows the in-built address/logical number of the robot functions.

The above-analyzed papers discuss the various improvements done in the robotic welding process by other authors. However, not many have worked towards improving the communication between the machine (robot) and the human. In this paper, we aim at developing a standard methodology for the interface HMI panel with the industrial robot. Also, three different jobs with different welding styles are welded in the same routine.

3. Industry Methodology

In this paper, the MOTOMAN AR1440 robot is interfaced with the Human Machine Interface (HMI) panel for arc welding of three different workpieces.

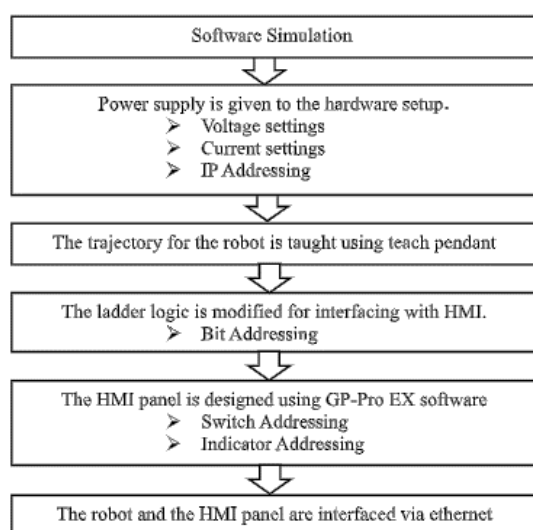


Fig 1. Flowchart of methodology

The methodology for interfacing the industrial robot with the Human Machine Interface (HMI) panel is explained in Fig.1. The three workpieces are welded using different welding

methods namely, Circular welding, tee weld, and butt welding respectively in a single routine.

Software Simulation of the Welding Process

In this paper, three different workpieces are considered for welding. Fig.2. shows the software simulation environment of the welding robot along with the workpieces. MOTOSIM-EG software developed by YASKAWA Robotics is used for the simulation of this welding process.



Fig 2. Design of the weld pieces

The position of the weld points is taught to the robot by offline pendant programming. The welding trajectory starts from the home position of the robot, welds along with the taught points of the workpieces and returns to the work home position. Fig.3 shows the robot with the weld gun along with the trajectory followed.



Fig 3. The trajectory of the welding process

First Workpiece: Circular welding is performed on the first workpiece. It is divided into 12 points. The weld torch is brought to each point and taught using a virtual teach pendant. MOVc command is used for circular welding. The CAD model of the first piece is shown in Fig.4.

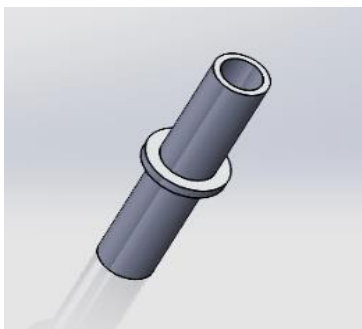


Fig 4. CAD model of the first workpiece

Second and Third Workpieces: Tee welding is performed on the second workpiece. Since it is a linear weld the robot is taught two points namely the starting and the ending point using the virtual teach pendant. Similarly, Butt welding is performed on the third workpiece. MOVL command is used for both the welding operation. The CAD model of the second piece and the third piece are shown in Fig.5 and Fig.6.

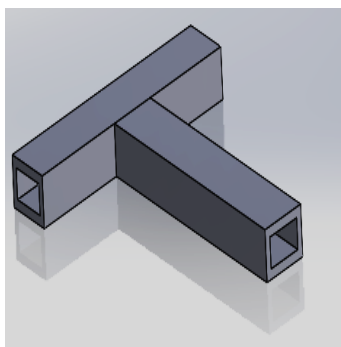


Fig 5. CAD model of the second workpiece

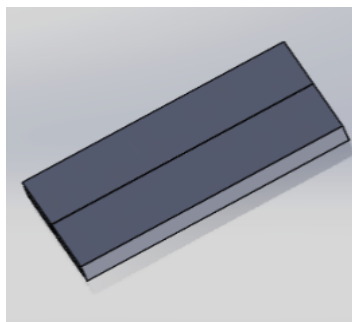


Fig 6. CAD model of the third workpiece

After simulating the welding process, the human-machine interface is designed to control the robot using GP- Pro software. The design process is explained in chapter IV in a step-by-step manner.

Hardware Setup

The hardware setup includes the MOTOMAN AR1440 robot, YRC1000 robot controller, Moto-weld transformer, Human Machine Interface panel, workpieces, and its fixtures.

Power Supply: The power connection is a significant factor for the uninterrupted welding process.

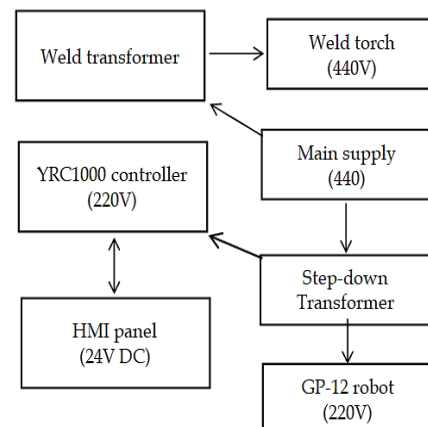


Fig 7. Power Circuit

Fig.7. shows the hardware connection of this experiment with the required power supply for each unit.

MOTOMAN AR1440 ROBOT with YRC1000 controller: AR1440 is a six-axis robot used in arc welding applications for fast and accurate performance. It has a wide range and provides the torch equal access to both sides of a part.

Table 1. Specification Of Ar1440 Robot

Power requirement	3-phase 380-480 VAC
Payload	12 kg
Weight	150 kg
Power rating	1.5 kVA
Frequency	50/60 Hz

Table 1 shows the specifications of the MOTOMAN AR1440 robot which is used for arc welding applications.

MOTOWELD Transformer – X350: Welding transformers are used to convert the AC into a low voltage and high current DC source. The Moto-weld and the YRC1000 are communicated via the Ethernet cable. Table 2 shows the specifications of the Moto-weld Transformer-X350.

Table 2. Specification of Moto-Weld Transformer

Rated Frequency	50 - 60 Hz
Rated Output Voltage	12 V - 36 V
Rated Output Current	30 A - 350 A
Rated input power	18 kVA / 15 kW
Applicable wire diameter	0.8mm, 0.9mm, 1 mm 1.2mm
Applicable Welding wire	Iron, Stainless steel Aluminum

HUMAN MACHINE INTERFACE Panel: Human Machine Interface (HMI) panel is a communication medium between humans and robots which enables both online monitoring and controlling the robot. It is a touch screen designed according to the application to help even a non-technician to handle the

robot at ease. HMI used in this project is a product of Toshnitek (Proface-HMI). Table 3 describes the specifications of the HMI.

Table 3. Specification Of Hmi Panel

Model number	PFXGP4114T2D
Series	GP4100
Size	4.3"
Resolution	480 x 272 pixels
Communication	Ethernet (IEEE802.3u) USB (Type – A) Mini-USB (Type – B)
Voltage	24V (DC)

The HMI panel and the YRC1000 controller are communicated via Ethernet. The controller and the robot are connected by a data cable. Fig.8. shows the overall experimental setup in an industrial environment for welding application.



Fig 8. Overall setup

Before starting the experiment, the initial industry settings must be ensured as shown in TABLE 4 and TABLE 5.

4. Implementation

Industry Settings Needed for Arc welding:

Table 4. Industry Settings

Robot mode	Management Mode
Electrode	ESSAAR copper coated steel wire (Wire Electrode)
Workpiece material	Stainless steel
The diameter of the electrode	1mm

Shielding gas	Carbon dioxide (CO ₂)
Voltage	12V
Current	70A

Table 4 shows the industry settings for this experiment. The voltage and current values are stored in the ASF and AEF files of the pendant which are accessed when needed. 12Volts is preferred for a good weld bead. Current is chosen by the Trial-and-Error method depending on the workpiece thickness.

Table 5. Current Analysis

Current (A)	Status
60	The workpieces melted
70	The workpieces did not melt and the bead width is observed to be around 2mm.
80	The bead was too thick
90	The workpieces melted
100	The workpieces melted

The thickness of the workpieces used in this experiment is less than 3mm. Hence the current rating must range between 60A to 100 A. Since the bead width is determined to be around 2mm at 70A (two times the electrode diameter it is chosen). Thus, the current value of the welding torch is determined using the Trial-and-Error Method as shown in TABLE 5.

Table 6. IP Address

192.168.255.200 (A1)	Controller IP address
192.168.0.20 (A2)	Computer (PC)
192.168.0.10 (A3)	Human Machine Interface (HMI)

The above TABLE 6 contains the IP address which is used to interface the robot and the HMI panel. A1 indicates the IP of the robot controller, which is used to interface the robot with the HMI panel. A2 is the address of the PC using which the panel is designed. It is used while transferring the project to the HMI panel along with A3 which belongs to the HMI panel.

Pendant Programming:

The trajectory of the end effector is taught using the teach pendant. Motosim EG software gives a clear understanding of the welding trajectory. The proposed algorithm for the experiment is shown below:

Input: HMI Command

Output: Welding Status, Alarm Condition

Initialization:

- 1: Initial Position of the robot
- 2: if (HMI Command=START) then
- 3: Circular welding is performed
- 4: Tee welding is performed

- 5: But welding is performed
- 6: end if
- 7: if (HMI Command=STOP) then
- 8: The welding Process is stopped.
- 9: end if

Ladder Diagram Modification

To interface the robot and HMI panel, the in-built ladder logic of the pendant is modified for the required features. The ladder programming can be edited in two ways: Mnemonic and Editing program, of which the program editing method is used in this paper. The steps involved in editing the ladder program.

Initially, the input and output addresses of the features to be modified are found using the YASKAWA manual. Fig.9 shows the image of the in-built ladder logic found in the pendant.

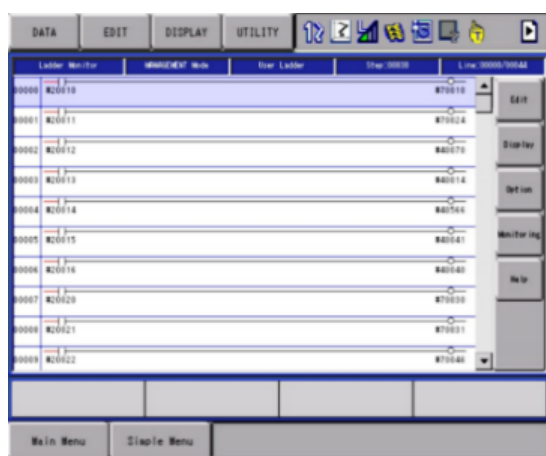


Fig 9. Image of In-built Ladder Logic

Find the range for assigning the new address in the pendant. Go to ladder editor in the teach pendant and choose the rung with the required features.

Copy the rung and paste it in the space below the ladder and connect a normally open switch in parallel and assign a new address. Fig.10 shows the modified ladder for one feature. Similarly, the ladder is modified for all the features.

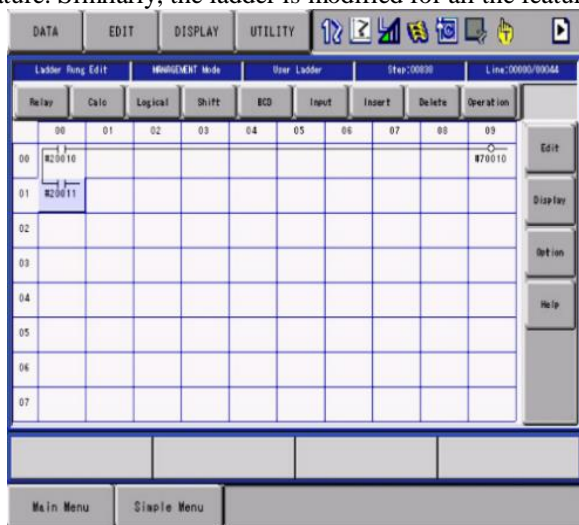


Fig 10. Modified ladder

The input address for the modified features along with their new input addresses are shown in TABLE 7.

Table 7. Bit Addressing

Input Address	Assigned Input Address	Output Address	Feature
20014	37020	30011	Servo ON
20010	37021	30010	Run
20011	37022	30012	Hold
20014	37023	30013	Emergency

HMI Panel Design

The Human Machine Interface (HMI) is designed using the GP-Proface software released by Schneider-Electric company. The Human Machine Interface (HMI) has three modes of communication of which Ethernet is chosen. The HMI panel is designed using GP-PRO EX software.

The panel is designed with four control switches and five indicators. The four switches are SERVO ON, START, HOLD, and EMERGENCY switches. The working of these switches is explained in TABLE 8. These switches are inter-linked with the ladder logic using a common input address. The address is shown in TABLE 8.

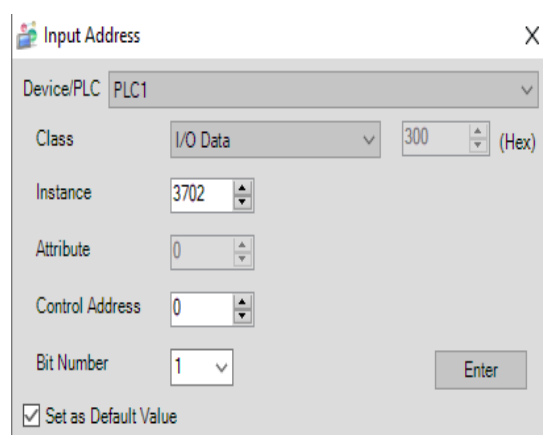


Fig 11. Input address to switch

The input address is assigned to the switches designed in the panel using the option shown in Fig 11. E.g.: 37021 is the address for the START command, 3702 is assigned in the instance box and 1 is assigned in the Bit number box. The same address will be given to the NO contact in the ladder editor. Similarly, the bit address is given for all the four switches according to the address shown in TABLE 8.

The panel also consists of five indicators, first three indicates the status of the three workpieces respectively, the fourth indicator indicates the welding status and the last indicator indicates the alarm condition. These indicators are interlinked with the string command in the pendant. Fig.12 shows the option for giving the input address to the indicators. The control address value 1 indicates the string value S001.

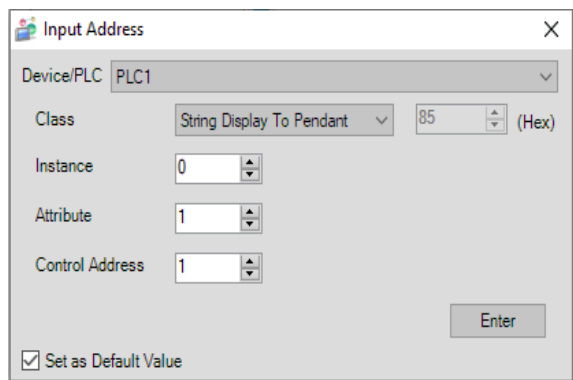


Fig 12. Indicator addressing

After giving the respective addresses for the switches and indicators, the project is simulated and transferred using the Transfer project option. Fig.13. and Fig.14. shows the settings in the software while transferring the project. In the transfer tool select send project, the HMI IP address will be displayed. Now choose the correct IP address to transfer the project. In the Transfer settings choose the communication type (LAN).

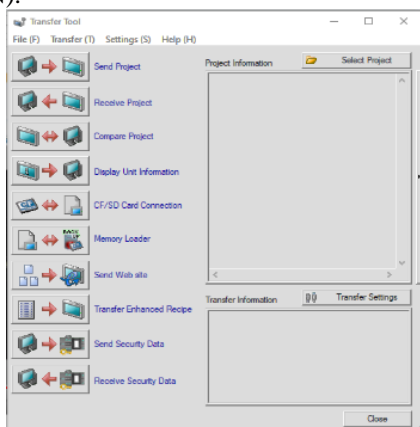


Fig 13. Transfer tool

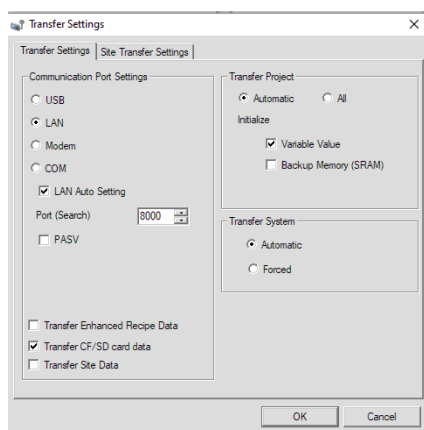


Fig 14. Choosing the LAN communication

Once the file is transferred to the HMI panel, interface the HMI panel and the YRC1000 controller using the Ethernet cable. Commands from the HMI panel reach the controller via Ethernet, which in turn controls the robot and weld transformer.

5. Results and Discussions

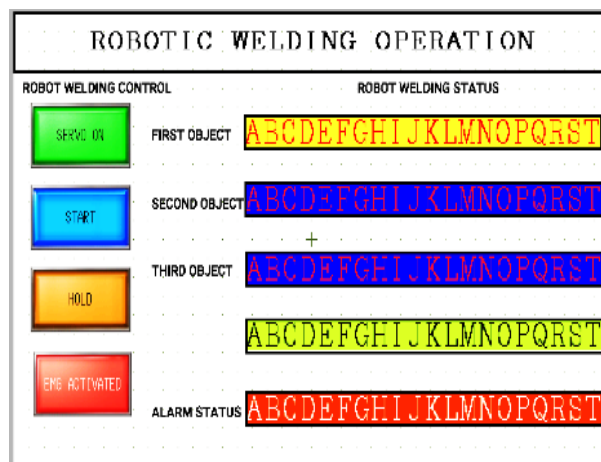


Fig 15. HMI design

Fig.15 is the HMI panel designed using GP-Pro EX software. The left side of the panel consists of control switches while the right side consists of status indicators.

Table 8. Specification of The Switches

Colour of the Switch	Name of the Switch	Function
Green	SERVO ON	Servo ON switch is used to start the servo motor on
Blue	Start	The start switch is used to run the program
Orange	Hold	Hold switch is used to pause the operation for a while.
Red	Emergency	Emergency switch is used to completely halt the program and to turn the servo OFF

Table 9. Specifications of The Indicators

Colour of the Indicator	Name of the Indicator	Function
Yellow	First object	Indicates the status of the cylindrical workpiece.
Blue	Second object	Indicates the status of the T workpiece.
Blue	Third object	Indicates the status of the rectangular workpiece.
Green	Welding status	Indicates the welding status (ON/OFF)
Red	Error / Alarm	Indicates an alarm in case an error occurs during the operation

TABLE 8 & 9 explains the switches and indicators used along with their functions. When the Servo ON button is

pressed, the controller has turned ON which in-turn gives supply to the robot. When the START button is pressed the robot will perform its welding operation. The status of the welding is displayed in the Human Machine Interface (HMI) panel. When the HOLD button is pressed, the robot performance is halted. In case of an emergency, we will get an alarm signal from the alarm status in the Human Machine Interface (HMI) panel and the emergency switch is pressed which in turn cuts the supply to the YRC1000 controller and the robot servo. Thus, we have designed the HMI panel and established a connection between the Human Machine Interface (HMI) panel and the robot. Using this we can now control the AR1440 robot to perform the welding operation for the three types of workpieces. Fig.16 shows the three types of weld pieces after the welding operation.

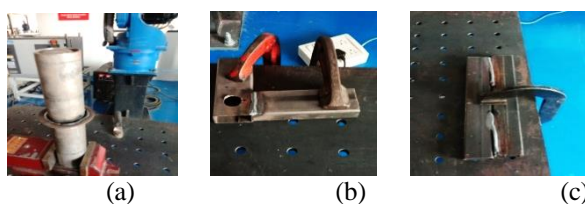


Fig 16. Welded workpieces (a) Circular weld, (b) Tee weld, (c) Butt weld

6. Conclusion

Thus, in this paper, we have simulated the welding process for three types of workpieces using MOTOSIM software. The errors in the trajectory are rectified by online pendant programming manually. The Human Machine Interface (HMI) panel is designed using the GP-PRO software and is used to control the welding process for the three types of workpieces at the same time. An industry methodology to interface HMI with a robot, controlled using a YRC1000 controller is developed and explained.

Future Work

The work is experimented with by interfacing the six-axis robot with a vision camera, to identify the workpiece and perform the corresponding welding operation independently using a CAD diagram. Moreover, other YASKAWA robots are interfaced with the human-machine interface panel following the industry interface methodology and experimented with other applications.

Acknowledgement

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Reference

- [1]. Jie Xu, Zhichen Hou, Jimin Liang, Wenlin Yang, Jian Wang, Weijun Wang, Xiangyu Bao, and Gong Zhang, "Advances in multi-robotic welding techniques: A Review," International Journal of Mechanical Engineering and Robotics Research, Vol.

- 9, No. 3, pp. 421-428, March 2020, doi: 10.18178/ijmerr.9.3.421428.
- [2]. Luigi Biagiotti, Lorenzo Moriello, and Claudio Melchiorri, "Improving the accuracy of industrial robots via iterative reference trajectory modification," IEEE Transactions on Control Systems Technology, Vol:28, Issue:3, February 2019, doi: 10.1109/TCST.2019.2892929.
- [3]. Amiel Hartman, and Vidya K. Nandikolla, "Human Machine Interface for smart wheelchair," Journal of Robotics, Article ID 4837058, 2019, doi: 10.1155/2019/4837058.
- [4]. P. Kah, E. Hiltunen, J. Martikaine, and M. Shrestha, "Robotic arc welding sensors and programming in industrial applications," International Journal of Mechanical and Materials Engineering, Article number: 13, 2015, doi:10.1186/s40712-015-0042.
- [5]. Tomasz Kosicki, "Cognitive human-machine interface applied in remote support for industrial robotic system," International Journal of Advanced Robotic System, January 2013, doi: 10.5772/56296.
- [6]. J.E. Middle, N.J. Street, and P.R. Shephard, "Development of an adaptive robotic welding system," International Journal of Production Research, Pages 869-877, 2007, doi: 10.1080/00207548608919773.
- [7]. J. Norberto Pires Altino Loureiro, P. Ferreira, B. Fernando, J. Morgado, and T. Godinho, "Using object-oriented and distributed software to assist industrial robotic welding applications," IEEE Robotics and Automation Magazine, July 2001, doi: 10.1108/01439910210419169.
- [8]. M.T. Abu Seman, and M. F. Rajemi, "Sustainable energy efficiency for MIG welding process," International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-8 Issue-5S, ISSN: 2278-3075, March 2019.
- [9]. Yukinori Hirota, "Measurement method of arc welding current and voltage," Welding Journal- Journal of Light Metal Welding and Construction, Vol.25., No 6, 441-443, May 2009.
- [10]. N. Nayak, A. Ray, "An integrated system for intelligent seam tracking in robotic welding. II design and implementation," IEEE International Conference on Robotics and Automation, 13-18, May 1990, doi:10.1109/ROBOT.1990.126285.
- [11]. Ugur Soy, Fehim Findik, Yasar Kiyani, Osman Iyibilgin, and Cemil Oz, "Determination of welding parameters for shielded metal arc welding," Scientific Research and Essays, Vol. 6(15), 2011, doi: 10.5897/SRE10.1073.
- [12]. G. Schroth, I. Stork, G. Wersborg, and K. Diepold, "A cognitive system for autonomous robotic welding," IEEE/RSJ International Conference on Intelligent Robots and Systems, 10-15, October 2009, doi:10.1109/IROS.2009.5354449.
- [13]. Marek St. Węglowski, "Industry 4.0 Vs Welding engineering," Research gate, January 2018, doi: 10.17729/ebis.2018.5/2.
- [14]. Gnanavelbabu, P. Arunagiri, and D. Dhanasekar, "Implementation of robotic welding for the improvement of production systems," International Journal of Engineering Trends and Technology (IJETT), V49(5), 304309, 2017, doi:10.14445/22315381/IJETT-V49P247.
- [15]. V.V. Ruiwale, A.A. Kadam, S.M. Kulkarni, and M.S. Jadhao, "A review on recent trends in robotic welding," International Journal of Engineering Science and Innovative Technology (IJESIT), Volume 4, Issue 5, September 2015.
- [16]. Z. X. GanH. Zhang, and J. J. Wang "Behavior-based intelligent robotic technologies in industrial applications," International Conference on robotic welding, intelligence and automation (RIWA '2006), China, December 8-11, 2006, doi: 10.1007/978-3-540-73374-4.
- [17]. Mehrdad Bahrami-Samani, S. Ali, A. Moosavian, and Maryam Agahi, "Design and analysis of a welding robot," IEEE International Conference on Automation Science and Engineering, 8-10, October 2006, doi: 10.1109/COASE.2006.326924.
- [18]. G.S. Bolmsjö, "Robotic arc welding - programming and control," ELSEVIER, Volume 21, Issue16, Pages 541-546, October 1988, doi:10.1016/S1474-6670(17)54665-0.
- [19]. Yaskawa Manual - YRC1000 OPERATOR'S MANUAL FOR LADDER EDITOR
- [20]. Yaskawa Manual - YRC1000 INSTRUCTIONS