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Original scientific paper

PROCEDURES OF WELDING METAL PRODUCTS WITH MIG/MAG ROBOT WELDING

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A b s t r a c t: This research paper describes robot welding programming and different approach of three applications in manufacturing processes by welding. It gives an overview of robot manipulator and its main components. For the experimental work a 6-axis robot arm is used and three different welds are made. Detailing of programming for every example with or without synchronization with the positioner and the trajectory is discussed. The paper presents steps of software development for online programming of a robot arm with or without synchronization.

Key words: robot; welding; programming

ПОСТАПКИ НА ЗАВАРУВАЊЕ МЕТАЛНИ ПРОИЗВОДИ СО РОБОТСКОТО ЗАВАРУВАЊЕ МИГ/МАГ

А п с т р а к т: Овој труд го опишува програмирањето на роботското заварување и различниот пристап на три апликации во производните процеси со заварување. Даден е преглед на робот манипулатор и неговите главни компоненти. Во експерименталниот дел се користи роботска рака со 6 оски и се направени три различни завари. Дискутирани се деталите на програмирањето за секој пример со или без синхронизација со позиционерот и траекторијата. Во трудот се претставени чекорите на развој на софтвер за онлајн програмирање на роботска рака со или без синхронизација.

Клучни зборови: робот; заварување; програмирање

1. INTRODUCTION TO ROBOTIC WELDING

Robots are very important equipment in today modern industry. The international standard ISO 8373:2012 defines a robot as "an actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks" [1]. Robot refers to any device or mechanism that performs intended tasks and meets three conditions at the same time: sense, think and act. Depending on the application area the classification in ISO 8373:2012 is accepted as industrial robots and service robots.

Welding plays a significant role in manufacturing, particularly in industries that use complex metal components and structures. One of the advantages of welding is the creation of joint with high strength but as disadvantage is the heating of the metal up to temperature of recrystallization and creating changes in thermos-deformation cycle [2].

To perform a quality weld requires experienced personnel who can control the process of welding. With the development of technology, creating a quality weld in short time and low cost for manufacturer become a need. With the development of Industry 3.0 and Industry 4.0 the automation of physical production processes is a key component for improving productivity and robots have played an important role in the automation of various operations, simultaneously enhancing the quality of manufactured products [3].

There are a huge number of products that require welding operations in their assembly processes and that is why industrial robots are most popular applications of robotics worldwide [4]. The car industry is probably the most important example, with the Metal Inert Gas (MIG) / Metal Active Gas (MAG) welding operations in the car body workshops of the assembly lines [5]. 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.

2. MIG/MAG ROBOT WELDING

Welding is the key factor in the development of industry, of every new construction made with metallic materials produced or used in constructions. In assembly processes every product requires welding operations with a good and highly automated welding process and to respond to client needs in time and quality.

MIG/MAG weldings, according to ISO 4063, proceses number 131 and 135 [6], respectively are widely used welding processes in industrial sector [7]. Uses heat created from an electric arc between a consumable metal electrode and a workpiece, creating a weld pool and fusing them together, forming a joint. The weld pool and the arc are protected from the environment and contaminants by a shielding gas, inert or active, depending on the chosen welding process.

Robotic welding is far from being a solved automatic technological process and this is due to the complexity of the process, difficult to parameterize and to effectively monitor and control. When welding with MIG/MAG, the process imposes extremely high temperatures concentrated in small zones, which makes the material experiencing extremely high and localized thermal expansion and contraction cycles, which introduce changes in the materials that may affect its mechanical behaviour along with plastic deformation [8].

3. COMPONENTS OF ROBOT WELDING STATION

A basic robotic arc welding station is composed of two subsystems: the welding equipment delivering the energy from the welding power source to the workpiece and the robot providing relative positioning of the heat source and the workpiece [9]. A typical robotic arc welding station includes moving mechanisms: welding tool manipulator aimed at moving the weld torch with required speed and orientation relative to the weld joint and positioning table for manipulation of the work piece (Figure 1). In this paper six-axis industrial welding robot is analyzed which is composed of a three-axis lower arm and a three-axis wrist, and they enable the welding torch mounted at the wrist to achieve all positions necessary for welding.

One of the integral parts of robotic welding station is the sensor technology. Sensing technologies designed for robotic welding are the essential elements for creating the desired level of control automation and monitoring. The sensors observe and measure process parameters, they are the input to the control system. With this input information the control system adapts output with the defined welding procedure specifications.

Another essential part of the robotic welding system is the robotic positioner whose role in the system is to hold, to rotate and reposition the part for the welding robot so that can reach the entire piece. It is obtained higher productivity and help automate tasks that would be impossible without rotational capabilities.

Fig. 1. Robotic arc welding station

4. EXPERIMENTAL WORK

For the experimental work a robot arm is used that has 6-axis movement. It is used in industry for advanced systems for adding filler material. The maximum range of the robot arm is 1374 mm and maximum payload is 6 kg (Figure 2).

Fig. 2. Robotic manipulator

The mobile unit has the function of managing the robot, including manipulation of all the processes required for welding. All functions such as programming are performed through the mobile unit for management and communication with the robot controller which is shown on Figure 3. The robot welding torch (Figure 4) is the element which stands on the arm of the robot, it has the function of a wire transmitter and conductor of the protective gas. With the help of the torch, a stable arc is created and thus a good weld joint.

Fig. 3. Mobile management unit AUR 010558

Fig. 4. Robot welding torch

5. AN APPROACH TO WELDING ROBOT PROGRAMMING

Programming of the robot remains the most costly and time-consuming task which demands a high degree of precision and reliability and basic knowledge of programming and robotics of the operator [10, 11].

Robot programming methods of industrial robots which play vital roles in welding are divided into online and offline programming [12]. With offline programming the method does not requires the robot and a virtual representation of the robot and its workspace is constructed. With online programming the method requires the presence of the robot and consists of recording the path with a management unit.

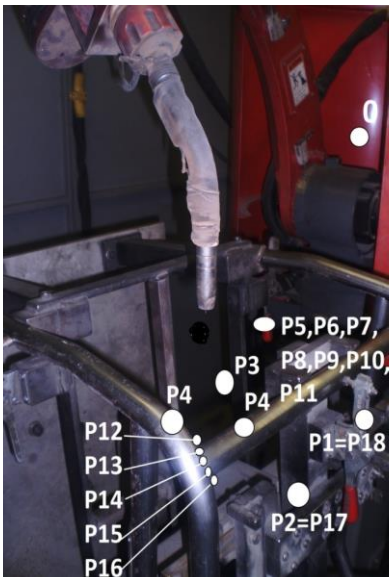
5.1. *Synchronized programming of chair*

The programming is done online with the mobile management unit. The trajectory of programming is shown in Table 1 and discussed below.

The next step is testing the program without welding, with good visual trajectory, approaching the future weld. The weld is performed with synchronization, the positioner rotates, moves, and the weld is performed in the best possible welding position. The welding program has 16 positions, the whole chair requires about 457 welding positions. There is a total of 10 complete or 20 individual welds. The welding process of the chair is 5 minutes (Figure 5) and on Figure 6 is shown one completed weld of the chair.

T a b l e 1

Trajectory of the programming



Position name	Task description
P0	Reset the sensor from the previous program (0 position).
P1	Deleting the previously saved points.
P2	Turn on the sensor before start.
P3	Approaching to tube with speed of 0.3 m/min
P4	Tube check with the weld torch, where there is a closed-circuit sensor
P5	Is saved as point GDI
P6	After each saving of the point the sensor is reset for a new point
P7	The sensor turns off
P8	Command to read the points, recall from memory
P9	Referring to sensed position
P10÷11	Moves according to sensing, the starting point is synchronized with the previous points
P12÷16	Setting the weld trajectory with 5 – points and speed S = 0,3 m/min, A = 90, V=14,7.
P17	Position 17 – turn off the sensor
P18	Resetting the sensor and erasing the previous points, returning to position 1
	Return to zero position.

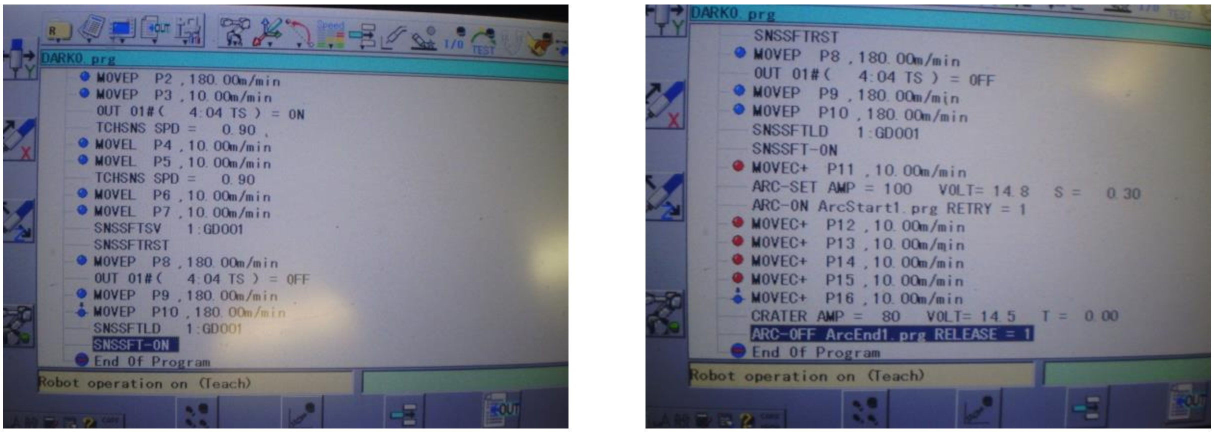


Fig. 5. Online programming of welding chair

Fig. 6. Completed weld with 16 positions

5.2. *Non-synchronized programming welds on "Plate 1"*

Welding programming is performed by online method, indirectly, where the welding program for the "Plate 1" is programmed with the mobile control unit. In non-synchronized welding the positioner does not rotate. The welding movement is performed by the robotic arm that moves along a given programmed trajectory. In such non-synchronized welding, welding in vertical or overhead position is not applied (Table 2).

Welding parameters are following:

- Welding current: 80-85 A
- Welding voltage: 14.5 – 14.8 V
- Welding speed: 10m/min

To perform all three welds, 20 positions were programmed, run the program without welding which is required for visual inspection and then perform the welding itself.

T a b l e 2.

Trajectory of programming of Plate 1

Position name	Task description
P0	Resetting the sensor from previous programs
P1	Deleting previous saved points
P2	Before starting linear movement, the sensor is turned off
P3	Starting point for the weld trajectory
P4	End point of the trajectory for the first weld
P5	Switch off the sensor
P6	After each point saving, the sensor is reset for new points
P7÷11	Moving along the weld trajectory and saving points
P12	Turn off the sensor
P13	After each point saving, the sensor is reset for new points
P14÷18	Turns on circular motion and moves along the trajectory of the circle
P19	Turn off the sensor
P20	Resetting the sensor and erasing the previous points
	Return to zero position

5.3. *Non-synchronized programming of "Plate 2" example with set amplitudes of welding gun movement*

In the third experiment, it is performed non-synchronized programming of example "Plate 2" with set amplitudes of movement of the welding gun. The welding parameters are the same as example no. 2, plate 1. To perform all three welds, 25 positions needs to be programmed. The program runs without welding, which is necessary for a visual inspection and then performing the welding. Non-synchronized welding with set amplitudes produces a wider weld and is used in thicker materials where a larger deposit of filler material is required (Table 3).

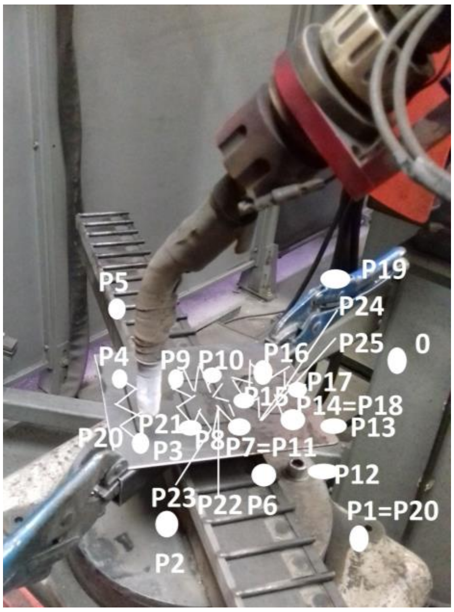
Welding parameters are following:

- Welding current: 80 – 85 A
- Welding voltage: 14.5 – 14.8 V
- Welding speed: 10 m/min.

To perform all three welds, 25 positions were programmed. Then run the program without welding, which is necessary for a visual inspection and then to perform the welding itself. Non-synchronized welding with set amplitudes produces a wider weld and is used in thicker materials where a larger deposit of filler material is required.

T a b l e 3

Trajectory of programming of plate 2



Position name	Task description
P0	Resetting the sensor from previous programs
P1	Deleting previous saved points
P2	Before starting linear movement, the sensor is turned off
P3	Starting point for the weld trajectory
P4	End point of the trajectory for the first weld
P5	Switch off the sensor
P6	After each point saving, the sensor is reset for new points
P7÷11	Moving along the weld trajectory and saving points
P12	Turn off the sensor
P13	After each point saving, the sensor is reset for new points
P14÷18	Turns on circular motion and moves along the trajectory of the circle
P19	Turn off the sensor
P20	Resetting the sensor and erasing the previous points
	Return to zero position

6. CONCLUSIONS

One of the important advantages of automated welding is precision and productivity. Robotic welding has an advantage over manual welding, the program is written only once, and will always produce precise and identical welds on parts with the same dimensions and specifications.

Automated gun movements reduce potential error, which plays a major role in production, waste management and repairs. With robotic welding, the risk of injury is minimized, and the impact of harmful fumes is minimized by distancing the worker from the work area.

The first example is performed with synchronization, the positioner rotates so that the welds are performed with positions that does not requires overhead and vertical welding. The second example is performed without synchronization, the positioner does not rotate and welding is performed in a plane. The second and the third example are performed without synchronization, but the third example is with set amplitudes of welding gun movement. Thus, the third example gives a wider weld than the second. This type of welding is used for thicker materials where it is necessary larger deposit of filler material.

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