Nonconventional Technologies Review
Romania, December, 2020

RESEARCH ON THE COMPARATIVE ANALYSIS OF PROCEDURAL DIFFERENCES BETWEEN MANUAL GTAW WELDING AND AN 8-AXIS ADAPTIVE ROBOTIC SYSTEM GTAW WELDING ON SPECIFIC SAMPLES

Andrei Mitru[1], Mircea Mitru[2] and Augustin Semenescu[3]
[1] National Research and Development Institute for Gas Turbines COMOTI, blv. Iuliu Maniu, no.220 D, Bucharest, Romania
andrei.mitru@comoti.ro
[2] National Research and Development Institute for Gas Turbines COMOTI, blv. Iuliu Maniu, no.220 D, Bucharest, Romania
m.mitru@yahoo.com
[3] University POLITEHNICA of Bucharest, Splaiul Independenţei, no.313, Bucharest, Romania, Academy of Romanian Scientists, 3 Ilfov, 050044, Bucharest, Romania, augustin.semenescu@upb.ro

ABSTRACT: The objective of the paper is concerning an 8 axis Adaptive Robotic System GTAW welding on 3,2 mm thickness test piece, base material stainless steel 304L with 1,2 mm diameter ER308L as filler material. The paper determines from the results obtained on test pieces, the current comparative analysis between the manual GTAW welding old process and the 8 axis robot GTAW welding new process. After the welding of the test parts, the application of the 8 axis robot GTAW welding new process requires a major initial investment which determines the decrease of the welding time by 50%, the decrease of the total parts execution time by 25% and the decrease of argon consumption by 44%.
KEYWORDS: **robotic system, gas tungsten arc welding, programming, procedure, time analysis**

1. INTRODUCTION

The implementation of the robotic welding process was applied by the companies with small or medium series production which became large series or even mass. This aspect appeared as a necessity to increase the production, to decrease the execution time, to decrease the production costs, to reduce the labour costs and finally resulting in products of superior quality.[1]

TIG / GTAW (Tungsten inert gas / Gas tungsten arc welding) is the welding process in which the electric arc is generated between a non-fusible electrode (from tungsten or tungsten alloyed with thorium, lanthanum or cerium) and the base metal of the joint parts. Thus, the generated electric arc leads to the creation of a molten metal bath which, by solidification, transforms the joint of the two pieces into a non-removable joint. The entire welding process takes place in an inert gas atmosphere (Argon or Helium) to protect the molten metal bath. Also, the welding process can be performed with / or without filler material depending on the requirements imposed by the documentation. TIG / GTAW welding process is widely used in most metallic materials: low alloy steels, stainless steels, super alloys (nickel, chromium or cobalt based alloys), titanium, aluminium or magnesium alloys.[2]

The TIG / GTAW welding process is a radiation, noise and gas generator. For this reason, the personnel related to the welding process must be provided with specific means of labour protection: anti-radiation equipment, protection masks with light sensor, earmuffs, air absorption and ventilation systems.[2]

Robotic welding systems tend to replace manual welding due to the advantages offered. Finally, the widespread application of robotic welding systems in the automotive, medical and aviation industries will make this process more reliable, easier to learn and apply.

2. OVERVIEW OF THE ADAPTIVE ROBOTIC SYSTEM

The application share of the robotic welding process in the world in 2011 was 12.7%. The increase in frequency of replacing the manual process of welding with a robotic process was also due to the use of similar devices for setting and fixing parts.[3]

In fact, the most used robotic welding processes are GTAW and GMAW (Gas metal arc welding). A robotic system consists of a robot, sensors, a robot console, a robot processor, an arc welding kit, a fixture device for positioning the pieces accurately, robot actuators for moving the robot axis.[2]

For the purpose of moving the welding torch in any direction, the welding robot must be programmed. Screws, chains, belts are holding together the robot components. The actuators used in manufacturing the robots are electric, pneumatic and hydraulic. Today, DC servo-motors and AC servo-motors have replaced the use of pneumatic and hydraulic actuators. The advantage of using AC servo-motors is that there is no maintenance required.[2]

The console is used by a programmer to teach the robot the desired positions and the orientation of the welding torch. After the teaching is done, a robot software program is obtained. During the program execution, the robot will perform according to all tasks recorded in teach session.[3]

A critical issue in welding robot path planning is obstacle avoidance. This issue can be resolved depending on how the teaching session of programming is performed. Hence, the programming process is time consuming and robot path planning must be based on optimization algorithms.[4]

Also, operator training is necessary. As a safety measure for the welding process, all obstacles should be cleared inside the robot working area. The welding process should be performed by the robot at a safe distance from the operator.[2]

(a) (b)

Figure 1. (a) Robotic system enclosure, (b) 3,2 mm thickness welded test piece

2.1 Programming of the adaptive robotic system

Data from sensors, peripheral equipment and process information is transferred to the robot controller. High heat deformation is important to take into consideration in arc welding. Sensors designed to prevent this issue are required to use. Manufacturing tolerances errors of the manipulator also must be taken into consideration.[2]

The controller stores in the robot memory all the programming data and values of the arc welding parameters. By means of controlling the robot, the controller performs all the computations. The robot actuators receive a signal from the controller which contains speed data, programmed position and information from sensors. Simultaneous coordinated control is required from the robot controller for welding a complex geometry work piece. Therefore, the brain of the welding robot is the controller.[2]

In the event of failure and losing the controller memory, USB storing data devices are recommended for having a back-up of the welding robot software program.[2]

There are four methods for programming a welding robot: using a teach pendant, manual operation, using a simulator and using the robot language.[2]

- Using a teach pendant method is accessible to qualified personnel because it's easy to use. Programming using a teach pendant can be performed by an operator who knows how to use a console for robot teaching. In the field of welding robots, a teach pendant is the first known device for programming. However, there are limited applications available for this method.[2]
- Using manual method for programming the welding robot is for a hard trained operator. This method was used in the beginning of robotic welding. In nowadays, this method is applied on spray painting robot applications.[2]
- Using the simulator method state that a translation is done into the language of the robot. This translation is in fact from a graphic simulation.[2]
- A keyboard and a display are necessary for the programming using the welding robot language. There are a couple of commands available and operation level languages. Only the goal of the process exists in the operation level language. Therefore, the motion of the welding robot is performed automatically. In conclusion, this method is still developing.[2]

Increased productivity means improved welding robot path planning. Collision-free path, welding deformation and optimization of path length are objectives that must be achieved in this matter.[4]

3. MANUAL GTAW PROCEDURES AND EXECUTION ALLOCATED TIME

3.1 Preparation for mounting

The procedure requires polishing with metallic stainless steel wire brush in areas adjacent to the weld on a width of approx. 15 mm, inside and outside, on both sides of the both test pieces. The penetration through the base material is 0,1 mm max. value. Straightening, adjusting and checking on the device of the uniformity of the welding joint and of the joint gap are completed during this phase. It is imposed that before the tack welding, the joint gap should be of 2-3 mm as evenly on both separation

lines. It is admitted that in areas where the joint gap is less than 1 mm, the edges of the joint should chamfered at 1,6 mm x 30 °.
The preparation time for this procedure is 10 minutes and the working time during the procedure is 90 minutes.

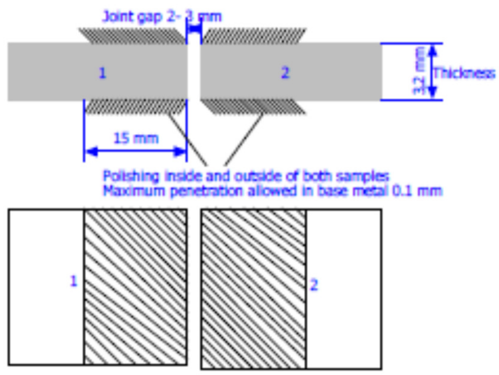

Figure 2. Preparation for welding with gap

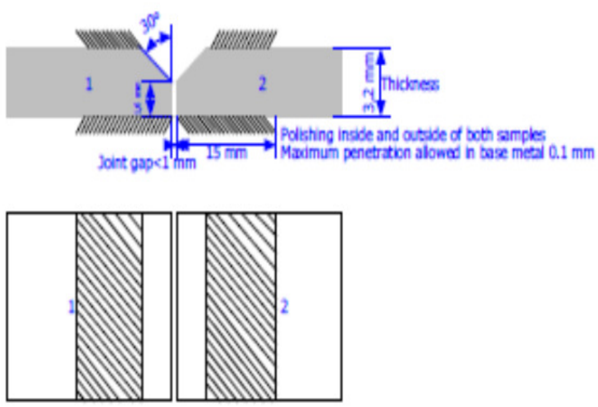

Figure 3. Preparation for welding without gap

3.2 Assembling

This procedure is done by positioning the technological cut-outs on the device portions. Tightening of the half-pieces in the device is a procedure objective, complying with the uniformity of the welding joint and with the joint gap.

The final step of the procedure consist in fixing the test pieces on 4 weak tack weld points on each side. The preparation time for this procedure is 15 minutes and the working time during the procedure is 90 minutes.

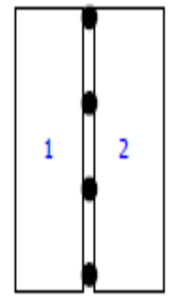

Figure 4. Four weak tack welds

3.3 Tack welding

A local degreasing with acetone in the inner and outer of welding areas is performed. The next step is fixing the test pieces with reduced penetration tack welds, with 30-40 mm pitch, on both separation lines, complying with the uniformity of the welding joint and with the joint gap. It is imposed that after the tack welding, the joint gap should be of 1-1,5 mm as evenly on both separation lines. The next step is polishing to metallic gloss the tack welding areas. At the end, a visual inspection of the welding tacks is performed for detection of possible surface defects and their correction, if any. The preparation time for this procedure is 15 minutes and the working time during the procedure is 15 minutes.

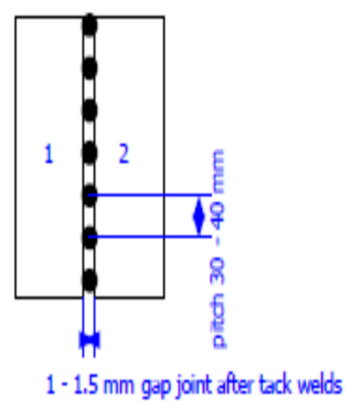

Figure 5. Tack welds

3.4 Straightening

The forth procedure is straightening and alignment of the test pieces on the joint line, on both sides, inside and outside. The preparation time for this procedure is 15 minutes and the working time during the procedure is 20 minutes.

3.5 Adjustment

Adjustment of the inner and outer at least 40 mm from the joint area of all traces, bumps and ridges is necessary. Also, adjusting the tack welds at the level of the base material to be completely embedded in the welding seam is a required step of the procedure. The preparation time for this procedure is 5 minutes and the working time during the procedure is 20 minutes.

3.6 Mounting

In order to weld the part, this procedure consist in mounting the stiffening device, the stiffening ring, the stiffening plate and the stiffening screw. The preparation time for this procedure is 5 minutes and the working time during the procedure is 20 minutes.

3.7 Argon welding

GTAW manually welding is performed on both sides, a total of 3 layers, 2 on the outside and one on the inside, the last layer being for completion. The preparation time for this procedure is 20 minutes and the working time during the procedure is 120 minutes.

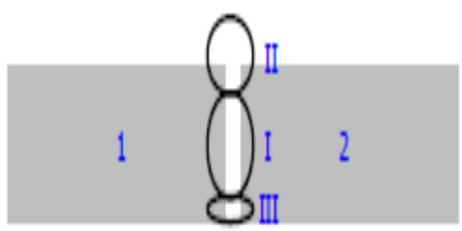

Figure 6. The order of layers is: I – Root layer, II – Covering layer, III – Completion layer

4. GTAW PROCEDURES AND EXECUTION ALLOCATED TIME FOR 8-AXIS ADAPTIVE ROBOTIC SYSTEM

4.1 Preparation for mounting

The procedure requires polishing with metallic stainless steel wire brush in areas adjacent to the weld on a width of approx. 15 mm, inside and outside, on both sides of the both test pieces. The penetration through the base material is 0,1 mm max. value. Straightening, adjusting and checking on the device of the uniformity of the welding joint and of the joint gap are completed during this phase. It is imposed that before the tack welding, the joint gap should be of 2±0,5 mm as evenly on both separation lines. *The edges of the joints should be unadjusted, unrounded, unchamfered so that the laser reading is as accurate as possible.* The preparation time for this procedure is 10 minutes and the working time during the procedure is 60 minutes.

4.2 Assembling

This procedures is done by positioning the technological cut-outs on the device portions. Tightening of the half-pieces in the device is a procedure objective, complying with the uniformity of the welding joint and with the joint gap. It is imposed that before the tack welding, the joint gap should be of 2±0,5 mm as evenly on both separation lines. Tack welding is performed on the outside each end at 40 - 50 mm both up and down. 3 spacers of 2,2 mm length are mounted on each side. The test piece is removed from the device. The preparation time for this procedure is 15 minutes and the working time during the procedure is 90 minutes.

4.3 Tack welding

A local degreasing with acetone in the inner and outer of welding areas is performed. The next step is fixing the test pieces with reduced penetration tacks, with 50 mm pitch, on both separation lines, complying with the uniformity of the welding joint and with the joint gap, considering that the tack welds should be as small as possible and should not exceed half the thickness of the test pieces. It is imposed that before the tack welding, the joint gap should be of 2±0,5 mm as evenly on both separation lines. The ends of the joints are welded on each side, about 50 mm down and upwards. The next step is polishing to metallic gloss the tack welding areas. At the end, a visual inspection of the welding tacks is performed for detection of possible surface defects and their correction, if any. The preparation time for this procedure is 15 minutes and the working time during the procedure is 30 minutes.

4.4 Straightening

Straightening and alignment of the test pieces on the joint line, on both sides, inside and outside is required. The preparation time for this procedure is 15 minutes and the working time during the procedure is 20 minutes.

4.5 Adjustment

This procedure is no longer required.

4.6 Mounting

In order to weld the part, this procedure consist in mounting the stiffening device and establishing argon backing. The preparation time for this procedure is 10 minutes and the working time during the procedure is 15 minutes.

4.7 Argon welding

4.7.1 External argon welding

This procedure, adaptive GTAW welding, consist in welding two layers at the outside on both sides. The preparation time for this procedure is 20 minutes and the working time during the procedure is 15 minutes.

4.7.2 Internal argon welding

This procedure is about manual GTAW welding of an inside completion layer on both sides. The preparation time for this procedure is 20 minutes and the working time during the procedure is 45 minutes.

5. CONCLUSIONS

Always, the application of a manual welding process has lower costs than a robotic welding process. Hence, only on projects that allow the most urgent recovery of the initial investment it is imposed to apply robotic processes. At the same time, the flexibility of applying robotic welding systems on as many jobs as possible must be taken into account.[1]

A time analysis on both presented procedures was done. The GTAW method with the 8 axis Adaptive Robotic System was determined to have the following advantages compared to the manual GTAW method:

- The welding time is reduced by 50% from 120 minutes to 60 minutes.

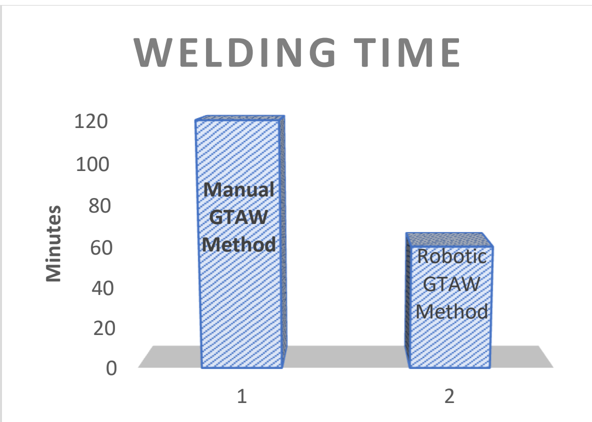

Figure 7. Welding total time

- The process total time is reduced by 25% from 370 minutes to 275 minutes.

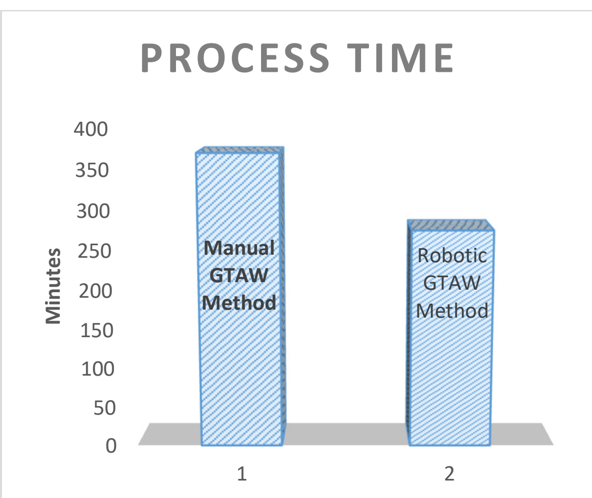

Figure 8. Process total time

- The argon consumption is reduced by 44% from 3,2 Nm3 to 1,8 Nm3.

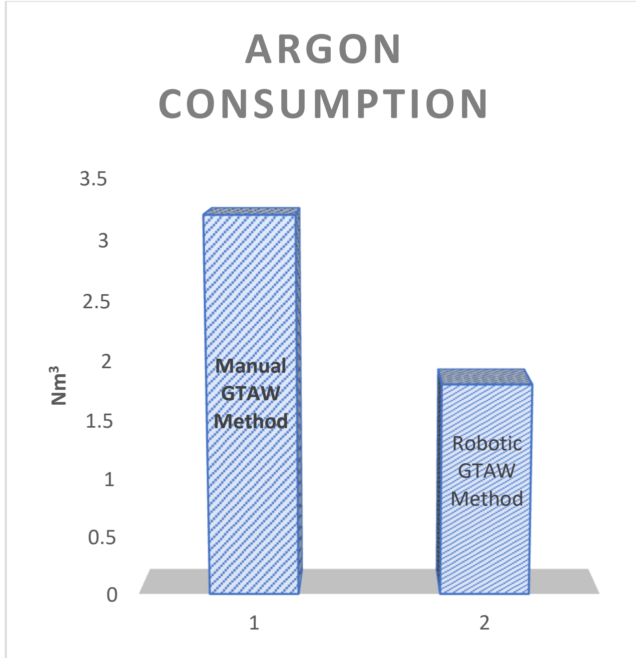

Figure 9. Argon consumption

6. REFERENCES

1. Bhagyashri G Chandankar, Viresh M Chapte, *Productivity Improvement in Welding Robot*, International Journal of Current Engineering and Technology, E-ISSN 2277 – 4106, P-ISSN 2347 – 5161, 2016.
2. Beom-Sahng Ryuh and Gordon R. Pennock, *Arc Welding Robot Automation Systems*, Industrial Robotics: Programming, Simulation And Applications, 2006, doi:10.5772/4918.
3. Nathan Larkin, Andrew Short, Zengxi Pan, Stephen Van Duin, *Automatic Program Generation For Welding Robots From CAD*, 2016 IEEE International Conference On Advanced Intelligent Mechatronics (AIM), 2016, doi:10.1109/aim.2016.7576827.
4. Wang Xuewu, Lika Xue, Yixin Yan, and Xingsheng Gu, *Welding Robot Collision-Free Path Optimization*. Applied Sciences 7, no. 2 (2017): 89. doi:10.3390/app7020089.