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ROBOTIC WELDING OF THIN-WALLED PARTS BY TOPTIG METHOD WITH WELDING MODE MONITORING SYSTEM

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The process of robotic TOPTIG welding of thin-walled T-joints and butt joints of nickel alloy Inconel 718 was developed. The welding installation TOPTIG 220 DC provides a wide range of adjusting the parameters in the process of non-consumable electrode inert gas welding with mechanized filler wire feed and possibility of robotizing welding in the places with a limited access to the weld zone. Based on the results of investigations of robotic TOPTIG welding, the technological features of making T-joints and butt joints of thin-walled parts of Inconel 718 alloy were determined. The measuring system of the installation provides registration of technological parameters of welding process, signaling about deviations from the preset values, formation of database on welding technologies and the possibility of their viewing. The carried out certification showed that the developed welding technology meets the requirements of standards EN ISO 15614-1 and EN ISO 15613. 7 Ref., 1 Table, 7 Figures.

Keywords: *robotic welding, TOPTIG method, thin-walled parts, heat-resisant nickel alloy Inconel 718, TOPTIG welding process monitoring*

In application of manual argon arc welding of thin-walled parts, the quality of welded joint depends largely on qualification of welders. To solve this problem, it was suggested to use the TOPTIG robotic welding method with a mechanized filler wire feed at the angle of 20° to the axis of a tungsten electrode [1–3]. In this method the system of mechanized feeding of filler wire is integrated with a gas nozzle, which allows reducing the dimensions of torch and expanding the opportunities of its application. In particular, the new torch provides an access to the places where application of traditional TIG welding torch with mechanized feeding of filler wire is not possible (Figure 1).

Below, as an example, the experience of developing the technology of robotic TOPTIG welding of thin-walled parts of the nickel alloy Inconel 718 with a system for registration of welding process parameters is described.

Development of technology of TOPTIG welding of thin-walled parts. The technological investigations were carried out in the welding station equipped with the welding robot CLOOS ROMAT 310 of Carl Cloos Schweisstechnik GmbH production and the welding installation TOPTIG 220 DC of Air Liquide Welding production.

The welded butt and T-joints of specimens were produced in accordance with the standard EN ISO 15614-1 [4] and those of the model parts were made in accordance with the standard EN ISO 15613 [5]. For welding the alloy Inconel 718 [6], the welding

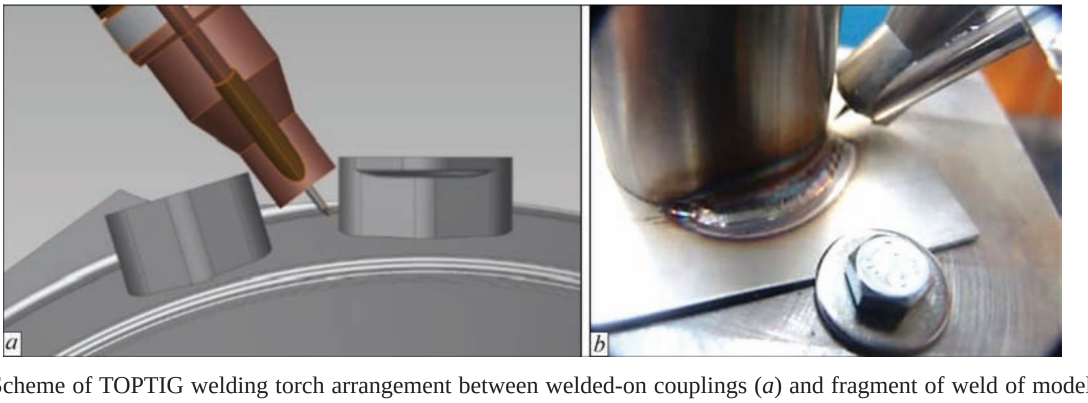

Figure 1. Scheme of TOPTIG welding torch arrangement between welded-on couplings (*a*) and fragment of weld of model element made by TOPTIG torch (*b*)

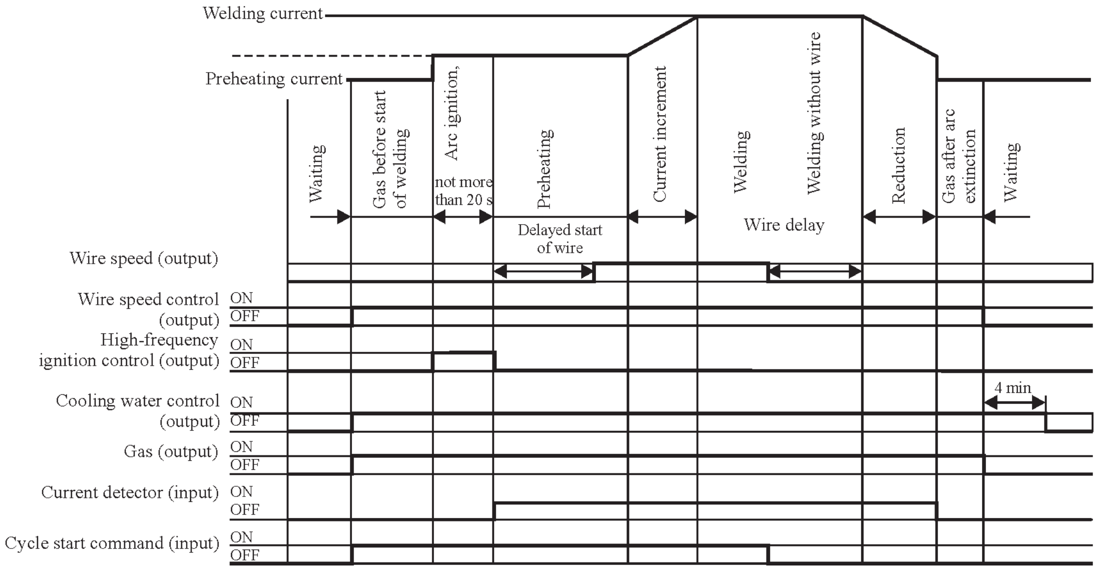

Figure 2. Time diagram of TOPTIG welding cycle [7]

wire NiFe19Cr19Nb5Mo3 of 1.0 mm diameter was used. As a shielding gas, high purity argon (ISO 14175-I1) of grade 4.8 (99.998 %) was used, and the consumption of argon was 15 l/min. The time diagram of TOPTIG welding cycle is shown in Figure 2.

When selecting the welding mode, it is necessary to take into account the peculiar features of the control system of the installation TOPTIG 220 DC, which provides the adjustment of pulsation of the wire feed speed and the possibility of synchronizing the wire feed with current pulses. Figure 3 shows oscillograms of welding current, arc voltage and wire feed speed in the TOPTIG welding process.

During the experiments the parameters of welding process were changed in a wide range and their influence on the course of the process and weld formation was evaluated. As a result of experiments, the modes of welding T-joints and butt joints were selected in the flat position, providing a stable process and the required quality of welded joints (Table). The macrostructure of welded joints is shown in Figure 4.

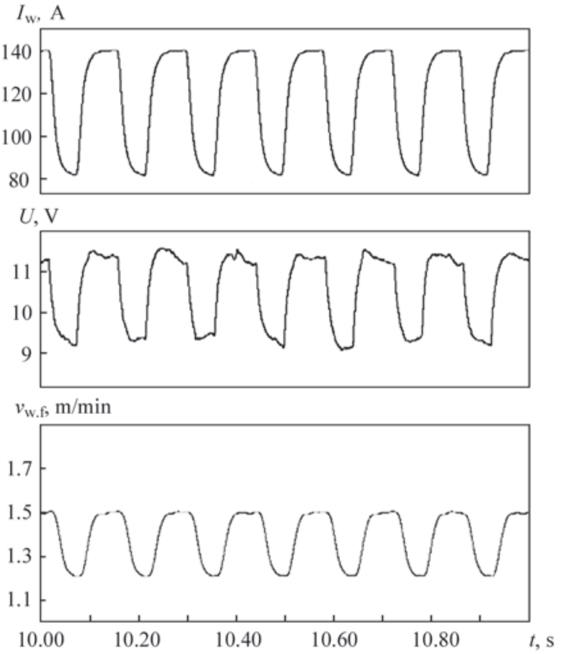

Figure 3. Oscillograms of current, arc voltage and wire feed speed during welding by the TOPTIG method

The carried out non-destructive testing and mechanical tests showed that the developed technology fully meets the requirements of the standards EN ISO 15614-1 and EN ISO 15613 on the welding process certification.

System for measuring and monitoring of parameters of the robotic TOPTIG welding process. Taking into account the high requirements specified to welded joints of the nickel alloy Inconel 718, it was decided to equip the serial robotic complex for TOPTIG welding with system for continuous monitoring of the welding process (Figure 5).

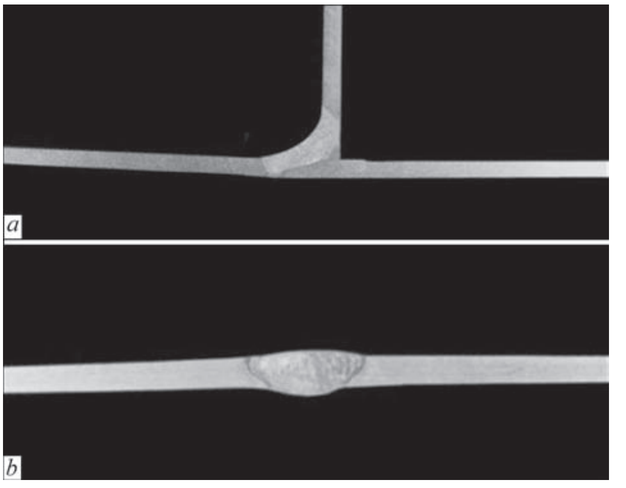

Figure 4. Macrostructure of T-joint (*a*) and butt joint (*b*) of 1.5 mm thickness, made by the TOPTIG method using welding parameters according to the Table

Range of adjustment of welding parameters in the installation TOPTIG 220 DC and the modes of welding the joints of 1.5 mm thick parts

Parameter	Adjustment range	T-joint	Butt joint
Time of gas supply before welding, s	0–10	1.0	1.0
Preheating current, A	5–220	100	70
Preheating time, s	0–10	1.4	1.4
Time of current increment before start of welding, s	0–10	0.5	0.5
Pulse current, A	5–220	140	130
Current in the pause between pulses, A	5–220	70	66
Pulse duty cycle, %	20–80	60	60
Pulse frequency, Hz	0.1–200	7	7
Welding speed, cm/min		26	29
Time of arc extinction, s	0–10	1.0	1.0
Time of stopping gas supply after the arc break, s	0–20	19	19
Initial delay of wire feed, s	0–10	1.0	1.0
Wire feed speed at the pulse, m/min	0–10	2.0	1.2
Wire feed speed in the interval (pause) between pulses, m/min	0–10	1.5	0.8
Delay in stopping the wire feed at the arc extinction, s	0–3	0.1	0.1

Based on the technical documentation of the equipment included in the robotic welding station and the results of carried out experiments, the parameters to be monitored, the method of interaction of the control systems of the welding equipment with the system of robot control were selected, and the locations for mounting the sensors of the monitoring system were determined.

The monitoring system was fully automated and its operation was synchronized with the operation of the control program of industrial robot, power source and TOPTIG welding head. When the welds (or their sections) are produced successively, the data on welding parameters are registered, processed, visualized and stored in the database.

The developed measuring system for monitoring the technological parameters of the TOPTIG welding process in the robotic station ensures the registration and recording of the following information in the database:

- welding current;
- arc voltage;
- consumption of argon supplied to the welding torch and for shielding the weld reverse side;
- purity of argon (analyzer signal of oxygen content in argon);
- welding speed (read from the robot program);
- wire feed speed;
- bar-codes: identification number of the part (welded unit), numbers of order, serial and reference numbers, numbers of welding operation (entered by the operator of the station using a bar-code scanner);
- name of welding program (read from the robot program);
- number of welding program (read from the TOPTIG installation by means of the robot control system);
- date and time of welding (it is read from the robot program);
- temperature of environment;
- relative humidity;
- dividing the weld into separate sections based on signals from the robot.

The computer program of measuring system is divided into several independent modules in the way to provide a preliminary determined functionality of the system. Figure 6 shows the main window of the module «OPERATOR», intended for the operator of the station. The program interacts with the module «REGISTRATOR», which sends the registered oscillograms of welding parameters in online mode.

In the program window several panels, including the diagram panels, information panel and signalization panels can be selected. Before the beginning of welding process the operator enters the data into the information panel (number of part, number of order, reference numbers, operation number) from the manufacturing plan of the workpiece to be welded using touch-screen or bar-code scanner. These data are attached to the oscillograms of welding parameters and

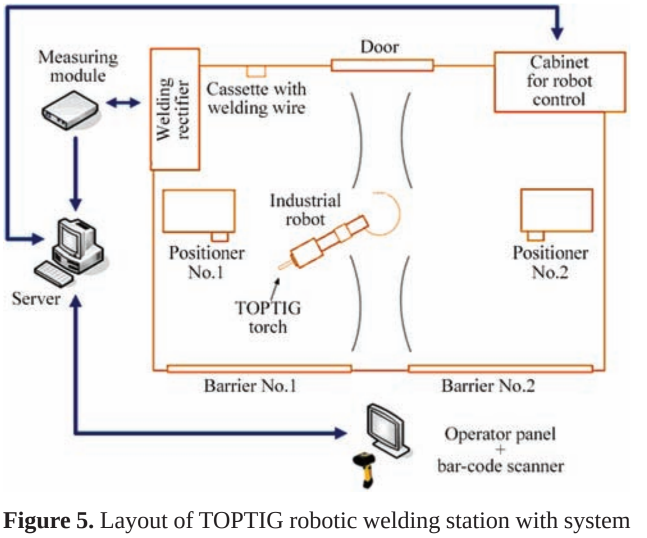

Figure 5. Layout of TOPTIG robotic welding station with system for monitoring the welding parameters

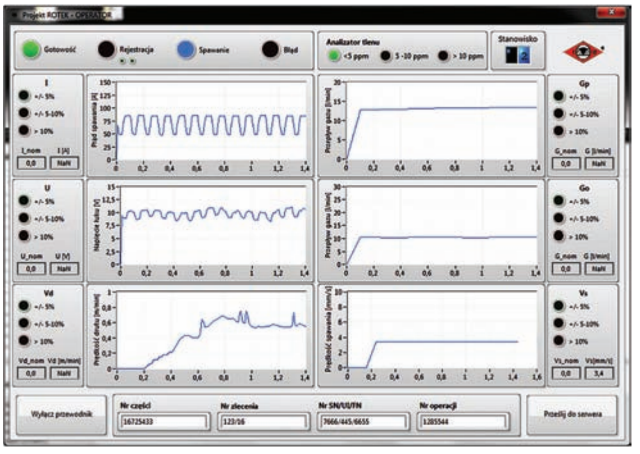

Figure 6. Graphical user interface of the software module «OPERATOR»

saved in the database. The signaling of violations of the preset welding mode is provided.

Figure 7 shows the main window of the module «VISUALIZER». The main task of this module is to view the archive data stored in the database. In this window, the following can be selected: diagram panel, which shows oscillograms of welding parameters; table of data records, in the strings of which the values of parameters for the next welds are stored; filter panel, with the help of which the subset of data based on certain parameters (e.g., number of part, number of order, serial number, operation number, number of robot program, date and time of the welding) can be selected. The program provides the ability to print the corresponding report according to the user's needs.

Conclusions

The welding installation TOPTIG 220 DC provides a wide range of adjusting the parameters in the process of welding by non-consumable electrode in inert gas with mechanized feeding of filler wire and the opportunity for robotizing welding in the places with a limited access to the weld zone. Based on the results of investigations of robotic TOPTIG welding, the technological features of making T-joints and butt joints of thin-walled parts of Inconel 718 alloy were determined. The carried out certification of the pro-

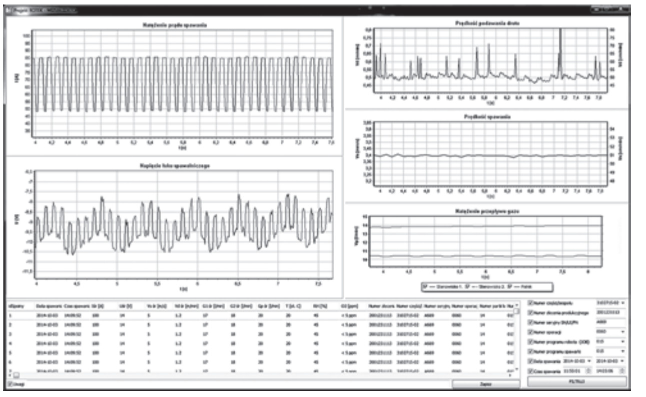

Figure 7. Graphical user Interface of the software module «VISUALIZER»

cess showed that the developed welding technology meets the requirements of standards EN ISO 15614-1 and EN ISO 15613.

The replacement of manual TIG welding of thin-walled parts by robotic TOPTIG welding improved the operation conditions of welders and ensured the high quality of parts being welded. The developed measuring system provides registration of parameters of welding process, signaling about deviations from the preset welding parameters, formation of data bank on welding technologies and possibility of their viewing.

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