

Innovative Robotic System for MAG Welding with Two Filler Metal Wire Feeders

Abstract: The article describes an innovative robotic MAG method for the welding for ship elements. The method involves the use of two wire feeders and one torch, making it possible to weld two different steel grades. In addition, the robot application is equipped with an off-line programming DTPS system (Desk Top Programming & Simulation System) as well as an arc sensor, a gas nozzle touch sensor and a laser touch sensor featuring a seam finding function. The system is also provided with a welding parameter monitoring and archiving system.

Keywords: MAG welding, robotic welding, welding wire feeders

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Introduction

Increasingly high costs of production, electric energy and labour force manufacturers of steel structures in all industries to search for possibilities of implementing automated and robotic welding not only in high but also in low-volume production. A challenge facing producers of robots and integrators is the development and implementation of applications, peripherals and tools enabling the obtainment of economic results in relation to short lots of products, particularly in the power engineering, extractive and shipbuilding industry.

Tools and applications aiding robotic systems

Software programmes for the simulation and off-line programming of industrial robots

The PANASONIC company has developed a system for the simulation and off-line programming of

robots known as the DTPS (*Desk Top Programming & Simulation System*). The DTPS software programme makes it possible to easily simulate the welding of various flat and spatial elements. The most important advantages of the software are the following [1]:

- creating the configuration of a system (so-called layout),
- possibility of entering external 3D CAD data,
- analysis of robot arm access,
- calculation of welding time and entire cycle time,
- collision control,
- off-line programming of the robot and the possibility of modifying existing programmes,
- programming does not require the interruption of robot operation.

All possibilities and advantages of the DTPS are discussed in the article entitled *Robotic Welding of Large-Sized Elements with Off-Line Aided Programming* published in *Przegląd Spawalnictwa* (*Welding Engineering Journal*) no. 10/2013 [2].

Sensors [2]

Przegląd Spawalnictwa no. 4/2018 concerning the 21st Conference on Welding Applications in Power Engineering contains an article entitled *Sensors in the robotic welding of large-sized elements and multi-run welds*. The paragraph below will only discuss the most important characteristics of the aforementioned sensors.

Arc Sensor

The use of the arc sensor is always connected with the oscillating movement of the torch performed between two elements during the welding process. At the aforesaid time, the robot performs the measurement of current and arc voltage. If elements are shifted in relation to the primary trajectory of robot arm movements, the value of electrode extension during oscillation increases or decreases, depending on the direction of displacement. A significant advantage of the arc sensor is its usability during the welding process, e.g. when an element subjected to welding undergoes deformations triggered by thermal stresses and the trajectory the robot arm changes accordingly. In the above-named case, the robot systematically corrects the welding path by measuring the value of current and maintaining the centre of oscillation precisely in the middle of the joint. The arc sensor can be successfully used in L-joints with fillet welds and in bevelled butt joints. The proper arc sensor operation requires the use of pulsed arc and a welding current of at least 200 A. Because of the above-named parameters, the arc sensor is applied in the welding of large-sized elements, where a sheet thickness amounts to more than 3 mm in cases of L-joints with fillet welds and above 5 mm in cases of bevelled butt joints. The arc sensor cannot be used in the welding of thin sheets (a welding arc of more than 200 A) as well as in the welding of edge joints and butt joints not previously subjected to bevelling.

Touch Sensor by PANASONIC

The software of the touch sensor features a library containing a large range of robot movements, both in terms of tool positions and in relation to the general system. After entering a related command with an appropriate movement direction, the arm of the robot starts searching for an element using the gas nozzle. Once the torch gas nozzle has touched the element, the arm stops automatically and the position of the current point is saved.

Touch sensor for bevelled plates (Groove Touch Sensor Function) by PANASONIC

The extended version of the sensor enables the detection of bevelled sheets/plates. The function makes it possible to precisely locate a joint and identify the size of the weld groove. Measurements are performed by a dedicated wire touching characteristic points of an element subjected to welding. To ensure the highest possible accuracy of measurements, the wire (during a measurement) is “locked” by a pneumatic actuator in a special welding torch.

Thick Plate function by PANASONIC – programming of multi-run welds

The programming of multi-run welds can be performed using two methods. The first (standard) method involves the developing of each run separately, whereas the second method assumes the application of special functions generating runs automatically. The PANASONIC company has developed an innovative “Thick Plate” software programme where the software developer only has to develop the first run, on the basis of which subsequent runs are created automatically. A related algorithm allows for changes in an inclination angle of the torch and its displacement in subsequent runs. The “Thick Plate” function also enables the welding of joints having the weld groove of the variable (irregular) width. In such situations, the frequency of oscillating movement is adjusted to the variable width of the joint.

Laser sensor (laser sensor function) by PANASONIC

Figure 1 presents an off-line laser sensor featuring a *seam finding* function. Laser sensors are characterised by greater versatility as they can be used to weld both thick and thin-walled elements, significantly extending the range of detection without compromising a detection accuracy of up to 0.3 mm (in relation to the sensor is located on the robot arm; robot accuracy being 0.1 mm). The sensor emits the laser beam which, after being reflected against a given element, returns to the receiver (CMOS matrix). Depending on the displacement of an element being tested, the returning beam strikes various areas of the receiver.

Data are converted to numerical values representing distances between the sensor and elements subjected to welding. The laser sensor is particularly useful in narrow spaces, where it is difficult to use the touch sensor; measurement distances can exceed 250 mm. An issue often accompanying the welding of large-sized elements is the purity of prepared joints. Rust or cinder, which frequently cover such elements, preclude the use of the touch sensor and make the operation of the arc sensor unstable. In the above-presented conditions, the analysis of displacements requires the use of a laser sensor (see Fig. 1).

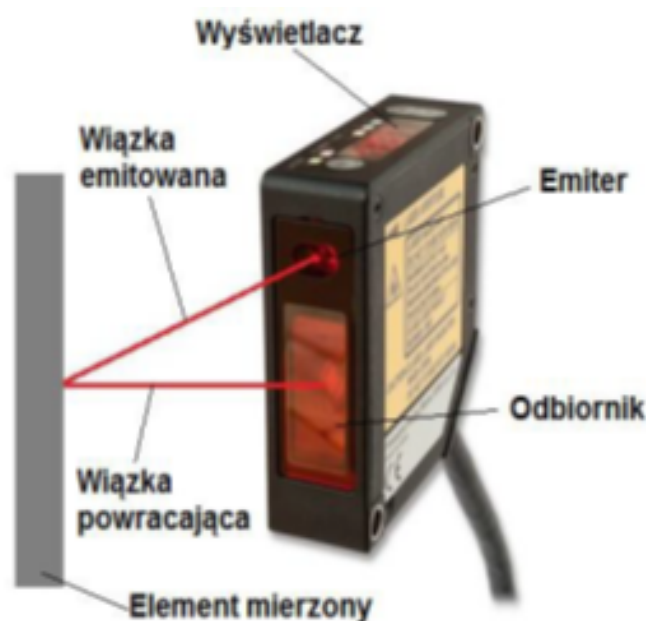


Fig. 1. Laser sensor – principle of operation

Laser video system (seam finding, seam tracking)

The state-of-the-art video system extends the possibilities of the laser sensor. The combination of scanning an element subjected to welding with the laser beam with the simultaneous analysis of the laser beam refraction by the digital camera provides enormous measurement possibilities, including the recognition of linear misalignment and characteristic shapes of joints. In comparison with the laser sensor (seam finding), connected directly to the robot, the video system requires an additional unit, usually a PC, processing (on an online basis) all data uploaded to the robot controller. Welding robots manufactured by PANASONIC include an ARC-EYE CSS video system (Fig. 2), compatible in terms of hardware and software. The identification of a welding path can take place both before (seam finding) and during (seam tracking) the welding process.

Robotic MAG welding system with two wire feeders

The leading manufacturer of ship structures commissioned the TECHNIKA SPAWALNICZA company with the development and making of a robotic station enabling the welding of an element having the following characteristics:



Fig. 2. Arc Eye function

- two steel grades:
 - unalloyed steel;
 - high-alloy acid-resistant steel
- length × width × height – 3000 mm × 2700 mm × 700 mm
- weight – 1000 kg
- single-run fillet welds having a thickness restricted within the range of 3 mm to 4 mm.

Robotic welding station

The station is composed of two work fields A and B (Fig. 3). The central part of the station contains a column-boom (no. 1). Elements attached to the column-boom include a robot, wire feeders, a welding torch with an anticollision system, wiring, a torch cleaning station, valves, sensors etc. The column torch (Fig. 7) can rotate by $\pm 180^\circ$.

Stations A and B are equipped with welding manipulators (no. 2) and support bearings (no. 3). The manipulators constitute the external axes of the system and communicate with the controller of the external axes of the robot. Special adapters are used for the attachment of frame bearers (no. 9) bolted to the manipulators and support bearings. The frame bearers enable the mounting of an element along with necessary

fixtures. In both stations (A and B) there are openings in the floor; the openings contain special drop pits (no. 4.). The right drop pit is in a position enabling operator to work. The left drop pit is open, enabling the rotation of an element and fixtures (for the purpose of clarity, the element with fixtures is not presented on the right side of the Figure). The drop pits (no. 4) enable operator's work at an ergonomic height of approximately 900 mm and make it possible to rotate the element with fixtures (maximum rotation radius being 1350 mm). The design of the drop pits is illustrated in Figures 4, 5 and 6. The primary elements of the drop pits are two hatches (no. 1, Fig. 4) and two side wings (no. 2, Fig. 4) used for bolting. The hatches and the side wings are fastened to the structure (no. 3, Fig. 4.) Figures 4 and 5 present the drop pit in the closed position, enabling safe operator's work. Figure 6 presents the drop pit in the open position, enabling the rotation of the element with fixtures. The drop pit is equipped with a pneumatic drive with actuators presented in Figure 6 (no. 1). The robotic station (Fig. 3) is also provided with the controller of the robot and of the external axes (no. 5), data transfer cabinet (no. 6), light curtains (no. 7) and housing (no. 8).

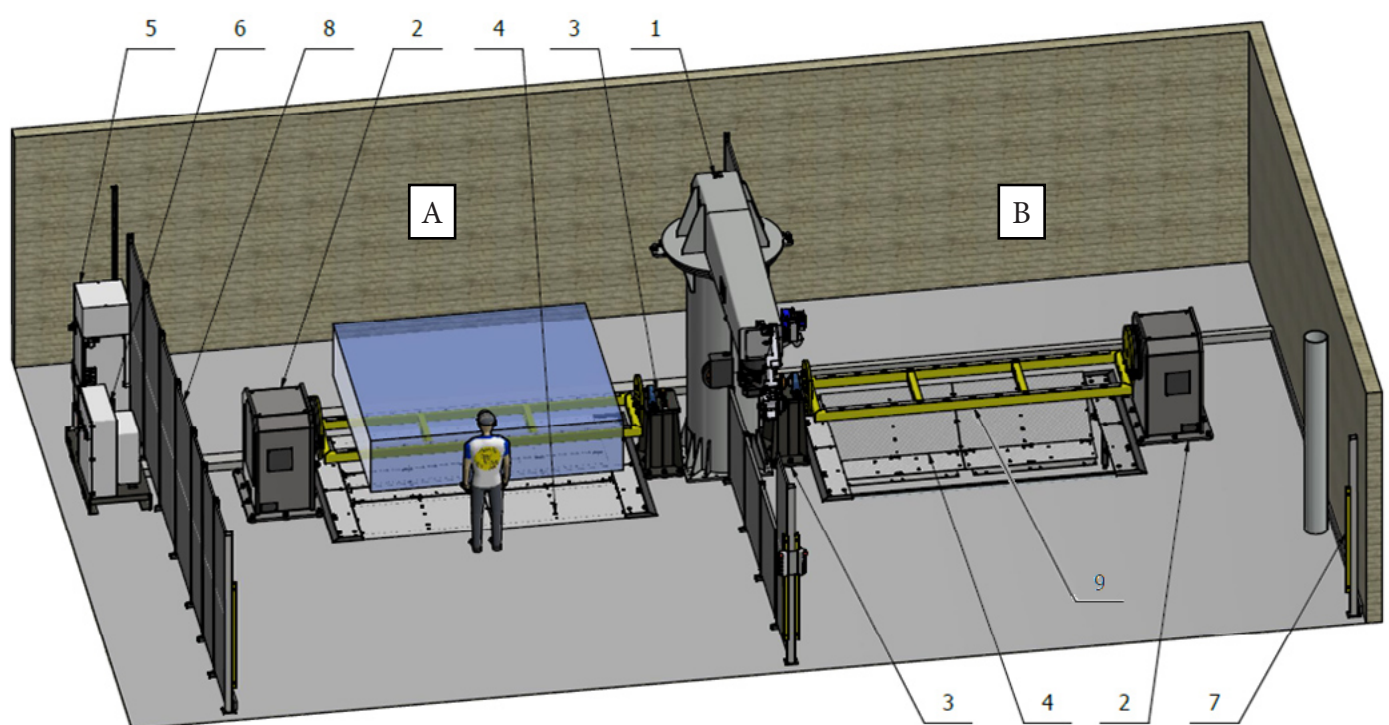


Fig. 3. Main view of the robotic station created in the DTPS

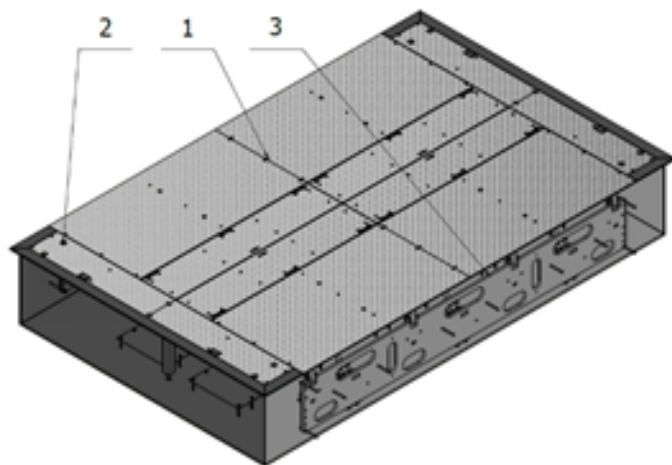


Fig. 4. Drop pit in the closed position

In addition, the robotic system is provided with sensors (invisible in Figures) of arc, gas nozzle touch (*touch sensor*) and laser touch (*seam finding*).

The configuration of the robotic system was created in the DTPS programme. Figures of fixtures were made in the CAD – INVENTOR PROFESSIONAL 2020 system and, along with the 3D Figure of the element subjected to welding, were entered into the DTPS. Because of this, the development of programmes and the course of the welding process can take place on an off-line basis (outside the robot).

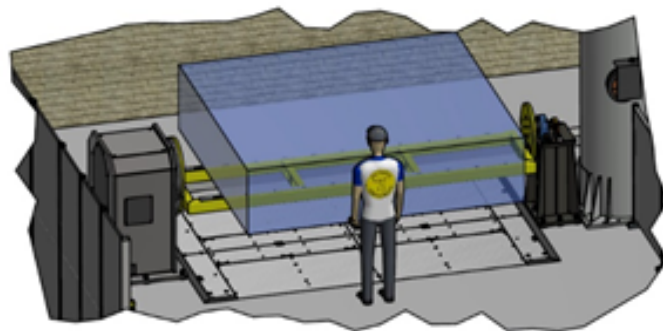


Fig. 5. Ergonomic work of the operator

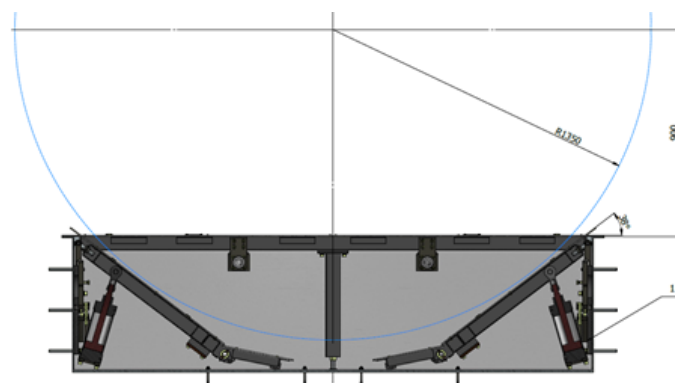


Fig. 6. Drop pit in the open position

The course of the welding process is continuously monitored. It is possible to record primary welding parameters and export them to the MS-Excel format (Fig. 8 and 9).

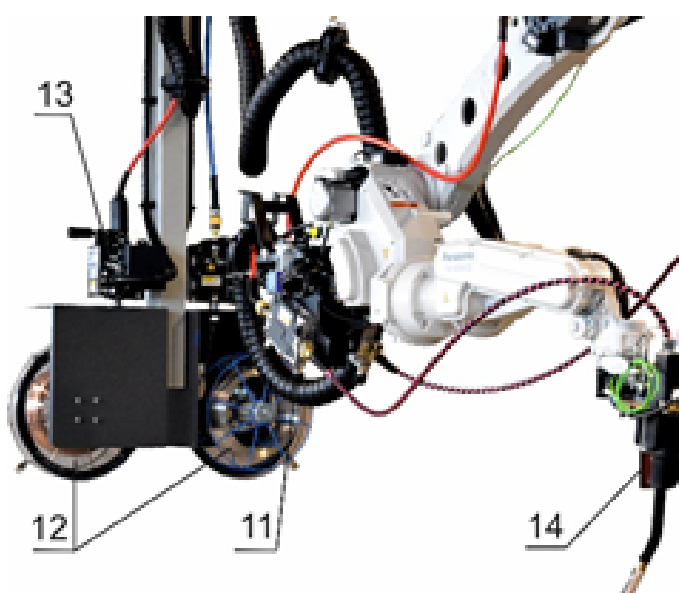
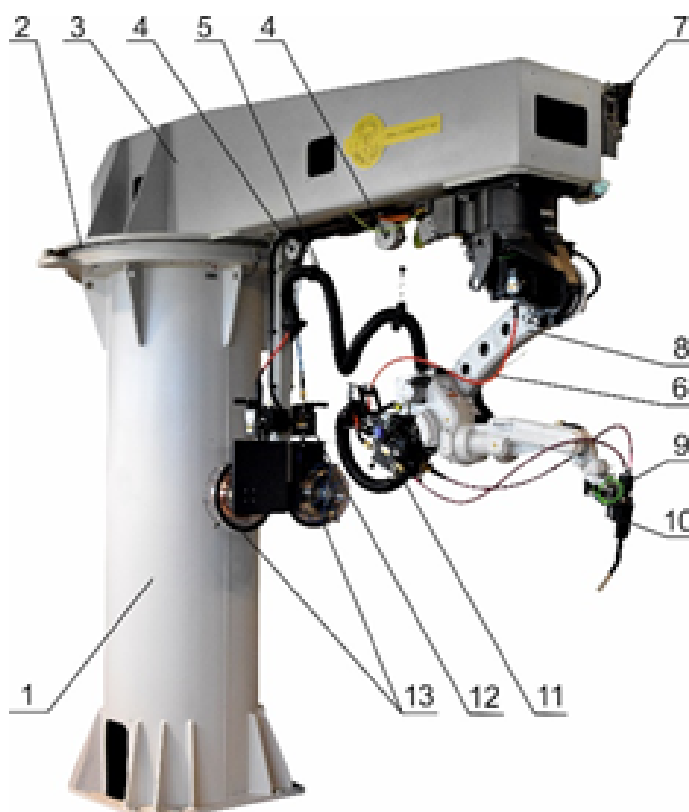


Fig. 7. Column-boom.

a) main view

b) robot with tooling

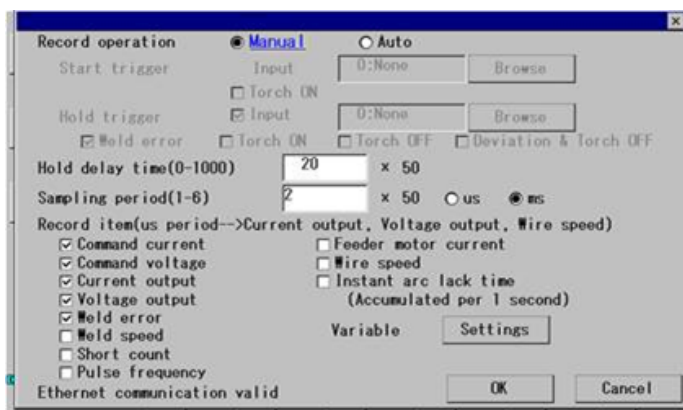


Fig. 8. Window for adjusting the parameters of the welding process

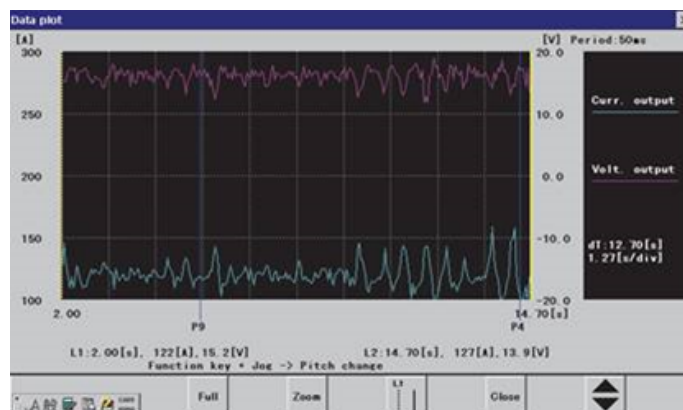


Fig. 9. Typical voltage wavelength and current wavelength during the welding process

Column-boom

The primary elements of the column-boom (Fig. 7a and 7b) are the following:

1. column;
2. system of column-boom rotation by $\pm 180^\circ$;
3. column-boom arm;
4. balancers lightening wire feeders;
5. unalloyed steel wire feeder;
6. high-alloy steel wire feeder;
7. torch cleaning and wire cutting station;
8. robot arm;
9. port interchangeably docking a wire (filler metal) for the welding of unalloyed steel and high-alloy steel (wires have the same diameter), the so-called "System Wire Switch";
10. welding torch with an anticollision coupling;
11. wire feeder (left and right);
12. system supporting the feeding of the wire (so-called "Wire Booster");
13. wire reel boxes (left and right);
14. laser touch sensor (off-line); the sensor is particularly useful where it is impossible to

access measurement areas with a torch gas nozzle as well as for lap joints and atypical T-joints (see Fig. 10).

The change of the filler metal wire is accompanied by the automatic change of shielding gas.

The course of the welding process is as follows:

- cutting of the filler metal wire in the wire cutting station (no. 7, Fig. 7);
- insertion of the wire from the torch neck to the wire docking port (no. 9, Fig. 7);
- extension of the wire from the docking port to the torch neck;
- cutting off the wire excess.

Primary technical parameters of the system:

- PANASONIC TM-1800WG3 robot with a TAWERS controller provided with an integrated welding power source and a Wire Switching system having an arm length of 1800 mm;

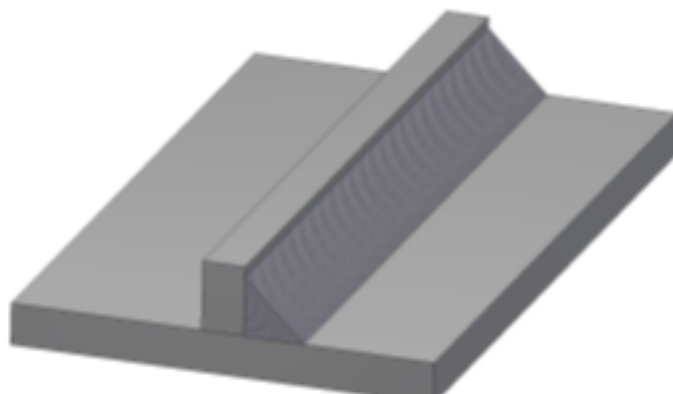
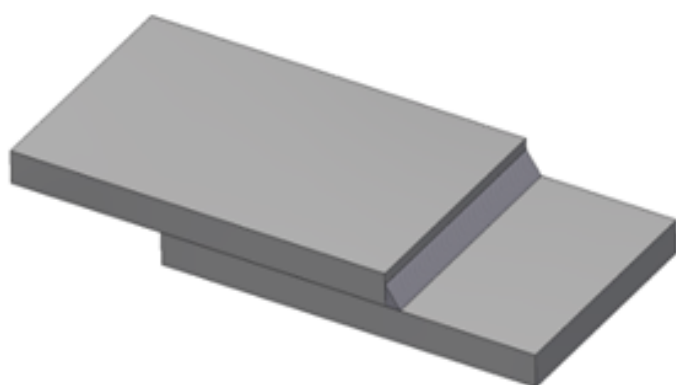


Fig. 10. Lap joint and the atypical T-joint

- welding power source parameters:
 - IP 32 (IP Code);
 - welding method – CO₂-shielded MAG welding, MIG welding; MIG/MAG pulsed current welding;
 - work cycle – 350 A 80% for CO₂-shielded welding, 350 A 60% for MIG/MAG pulsed current welding;
 - welding current range of 30 A DC to 350 A DC;
 - voltage range of 12 V DC to 36 V DC;
- two PD2000 welding positioners having a lifting capacity of 2000 kg. provided with a PANASONIC drive;
- operating fields having dimensions of 3000 mm × 2700 mm;
- rotating column-boom +/-1800 having an arm length of 2400 mm.

Conclusions

1. The use of two types of sensors, i.e. a mechanical touch sensor and a laser touch sensor enabled accessing all types of joints with fillet welds and made it possible to perform a welding process representing quality level B of the PN-EN ISO 5817 standard.
2. The use of an innovative solution including two wire feeders and one welding torch significantly increased welding process efficiency.

References:

- [1] Nowak M., Wiśniewski D., Buchowski J.: Sensory wspomagające zrobotyzowane spawanie elementów wielkogabarytowych i spoin wielościęgowych. Przegląd Spawalnictwa, 2018, no. 4, pp. 4–8.
- [2] Nowak M., Wiśniewski D., Buchowski J.: Zrobotyzowane spawanie wielkogabarytowych elementów ze wspomaganie programowania off-line. Przegląd Spawalnictwa, 2013, no. 10, pp. 19–28.