# ARC SPOT WELDING OF OVERLAP JOINTS IN VERTICAL POSITION

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The technology for vertical spot metal-arc welding of sheet metal without preliminary piercing of holes in the external sheet was developed. Adjustment of parameters of the welding cycle allows producing the high-quality spot joints.

**Keywords:** *gas-shielded welding, spot overlap joints, structural steels, vertical position*

The arc spot welding (ASW) technology used to weld sheet metal finds application in car building, aircraft engineering, ship building, motor car industry and construction. The ASW technology provides high productivity and quality of operations, saves time and materials. The process is advantageous in the possibility of producing sound overlap joints both without and with holes made in workpieces, as well as fillet and T-joints [1–7].

The car building industry uses mainly semi-automatic $CO_2$ welding. This method allows making up to 80 % of all the welds, including the arc spot welds. In manufacture of railway cars, sometimes it is necessary to make spot joints in a vertical position. To reduce labour intensity, it is expedient to make some horizontal welds on a vertical plane by ASW.

In ASW of metal over 1.5 mm thick in the vertical and overhead position, it is recommended to make holes in the external sheet [1–3]. Given that ASW is performed with the semi-automatic device by switching on and off of feeding of the welding wire, the quality and consistency of sizes of the resulting spot welds are determined by the skill of a welder. In addition, when performing ASW on the vertical plane it is necessary to overcome difficulties associated with retention of the molten pool metal. Independently of the welder's skill, production of the sound welds can be achieved by programming parameters of the welding process. Existing equipment and technology do not always provide sufficient stability of the welding parameters and, as a consequence, preset sizes of the spot welds according to GOST 14776--79 [8]. Decrease in quality of the joints may be caused by probable deviations. Some welding power supplies have the possibility of programming time of the welding cycle (welding wire feed speed is usually not programmed).

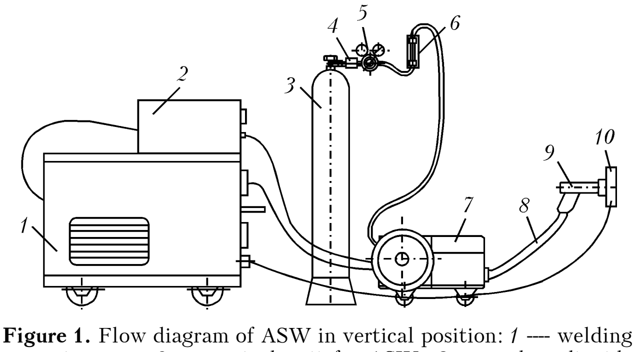


**Figure 1.** Flow diagram of ASW in vertical position: *1* --- welding current source; *2* --- control unit for ASW; *3* --- carbon dioxide gas bottle; *4* --- pre-reducer drier; *5* --- reducer; *6* --- gas flow rate meter; *7* --- electrode wire feed mechanism; *8* --- flexible hose cable; *9* --- welding torch; *10* --- workpiece

The task of this study was to provide the sound spot joints on the sheet metal in a vertical position without preliminary piercing of holes in the external sheet. Accomplishment of this task involves difficulties associated with retention of the molten pool metal, as well as with ensuring of reliable ignition of the arc in the initial period.

The experimental machine for $CO_2$ arc spot welding in a vertical position (Figure 1) was developed to fulfil the task posed. This machine consists of a welding current source of the VDUCh-500 type, welding wire feed mechanism PDG-500-4, specialised control unit, welding torch with a specialised nozzle, and a lever clamp providing elimination of a gap between the pieces joined.

Characteristic feature of the ASW process is separation of the welding cycles into stages, which differ in their technological purpose and welding parameters [3, 5]. The welding cycle without preliminary piercing of holes in the external sheet is performed in the following stages:

- heating of the surface of an external piece;
- burning through of the external piece and penetration of the second piece. A hole being formed in the external piece and partial penetration occurring in the internal one;
- filling up of the formed hole with molten electrode metal;
- welding up of the crater in the spot weld.

ASW in the vertical position performed under the conditions used for making spot joints in the flat position failed to give positive results. The weld spots had a number of essential defects, such as incomplete filling of the weld pool with electrode metal caused by its flowing down, formation of rolls of the flown-out metal, and undercuts (Figure 2).

Reproducibility of the weld spots was low, which was caused by a considerable effect of the following factors:

**Figure 2.** Spot joint made in vertical position under the conditions used for ASW in flat position

• different conditions of arc ignition caused by different sizes of the electrode metal drops solidified at the welding wire tip after each welding pulse;

• high heat input into a welded joint: molten metal flows out from the weld pool;

• effect of the gap between the pieces joined and shielding gas flow rate on the appearance and quality of a spot joint;

• shape of the welding torch tip;

• stability of the welding wire feed: the probability of slippage of the wire leads to inaccurate portioning of the depositing metal in formation of a weld spot;

• presence of various contaminants on the surfaces of the pieces joined.

While optimising the technology of ASW in the vertical position, the spots were made on experimental samples (Figure 3) using 1.6 mm diameter solid wire Sv-08G2S and $CO_2$ as a shielding gas.

To control heat input in making a spot joint, the time pauses between the welding pulses were added to the program of changing the process parameters of welding in the flat position. The program of changing the welding process parameters shown in Figure 4 provided the portioned addition of metal to the weld pool by alternating the welding cycles, as well as the reliable ignition of the welding arc. The need for the reliable arc ignition is attributable to the fact that in metal arc welding the arc does not always starts burning from the first touch, this having a significant effect on implementation of the programmed parameters of spot welding.

The stable arc ignition in ASW is achieved by decreasing the welding wire feed speed at the initial moment of welding (time period $t_1$). At the required wire feed speeds there is enough time for heating and

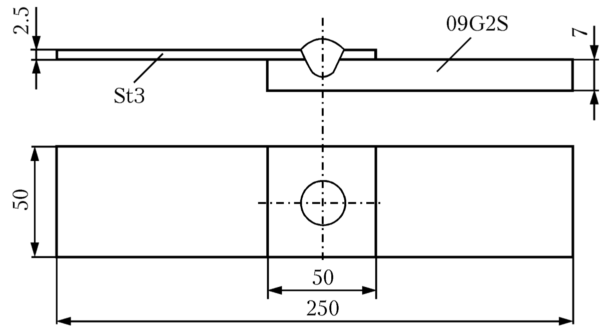


**Figure 3.** Schematic of experimental sample

melting of the electrode tip, which increases the probability of the arc ignition. At the high wire feed speeds the arc ignition stability decreases to a considerable degree.

The portioned heat input into the weld pool is ensured by alternating welding pulses and pauses, as well as by regulating their time, thus providing the optimal welding cycle, as well as more favourable structure and properties of the weld metal. Cooling of the weld takes place in intervals between the welding cycles, which prevents flowing of the molten metal from the weld pool and provides the satisfactory weld spot formation. Durations of pulses and pauses between the pulses, as well as the welding current are set, which makes it possible to form the final volume of the weld spot and its external surface. As noted in [4, 7], the stressed state in cyclic heat input into a welded joint is much lower than in welding performed under the conditions without pauses between the pulses, or under the conditions without pulses. The ASW parameters can be varied over a wide range, depending upon the ASW cycle, thickness of the pieces joined and diameter of the electrode wire.

Burning through of the first piece with formation of a hole, and partial penetration of the second piece are performed in cycle $t_2$. Welding in this period is performed under increased parameters.

Welding cycles in time periods $t_4$ and $t_6$ provide filling up of the formed hole after the welding cycle in time period $t_2$ and formation of the weld spot. The first cycle with duration $t_4$ is performed so that 50--60 % of volume of the deposited metal of the weld spot is provided. Completion of the second cycle (with

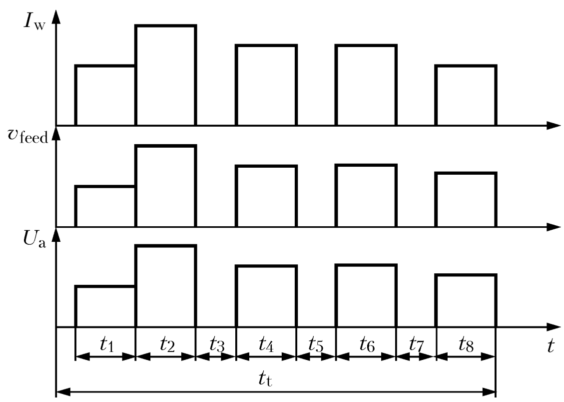


**Figure 4.** Program of changing of process parameters in ASW in vertical position: $t_1$--$t_8$ — duration of pulses and pauses; $t_t$ — total time of the ASW cycle

Parameters of arc spot welding of sheets 2.5 + 7.0 mm thick

| Welding cycles | $U_w$, V | $I_w$, A | $v_w$, m/h | $t_w$, s | $t_{pause}$, s |
|---|---|---|---|---|---|
| $t_1$ | 26–28 | 180–220 | 100–120 | 0.4–0.5 | – |
| $t_2$ | 40–42 | 450–500 | 280–300 | 1.0–1.3 | $t_3$ = 1.5–2.0 |
| $t_4$ | 28–30 | 230–250 | 140–160 | 0.8–.1.0 | $t_5$ = 1.0–1.5 |
| $t_6$ | 28–30 | 230–250 | 140–160 | 0.8–1.0 | $t_7$ = 0.5–1.0 |
| $t_8$ | 24–.26 | 170–190 | 100–120 | 0.5 | – |

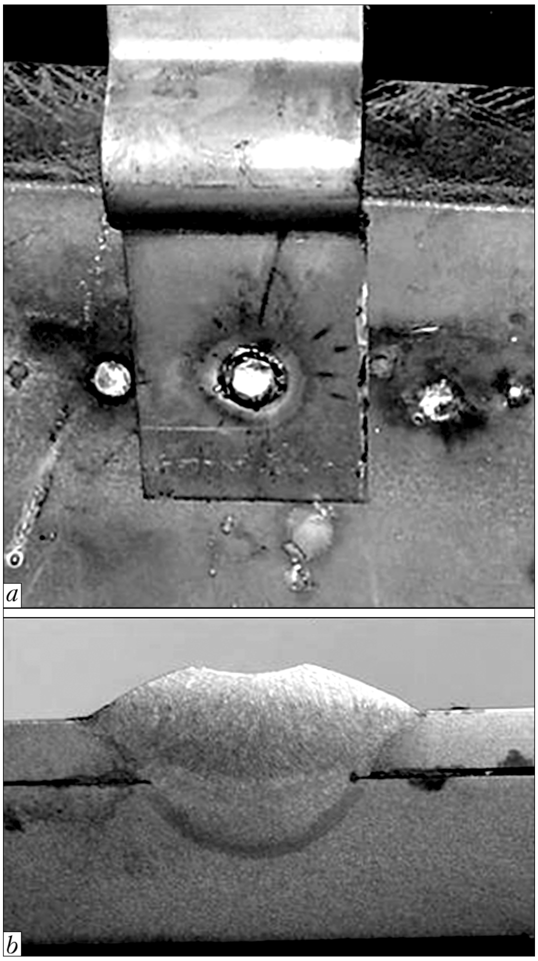

**Figure 5.** Appearance of spot welded joint produced by ASW in vertical position (*a*) and its macrosection (*b*)

time $t_6$) allows formation of the final volume of the weld spot. Cooling of the deposited weld metal takes place in time periods $t_3$, $t_5$ and $t_7$ (durations of pauses between the welding cycles). The durations of pauses are set so that the deposited metal volume could solidify during these time periods. Welding up of the crater and formation of the appearance occur in the last welding cycle (time interval $t_8$ according to the scheme of changing of the welding parameters).

Selection of optimal parameters of ASW was carried out on samples by changing the arc voltage, setting the optimal welding wire feed speed at each welding cycle, and by optimising the time of each welding cycle and pauses between them. The welding parameters are given in the Table.

The quality and size of the spot welds are strongly affected by the duration of each cycle and stability of the welding parameters. Parameters given in the Table provide the high-quality spot joints, which is confirmed by the results of metallographic examinations. As shown in Figure 5, the spot joint has a sound appearance, and rolls of the flown-out metal are absent. The macrosection confirms the absence of undercuts and defects of the type of pores, cracks and slag inclusions. The penetration depth in this case is 3.5 mm, and diameter of the weld spot nugget is 8 mm.

As proved by the investigation results, strength of the weld spot depends upon the metal thickness and diameter of the weld spot nugget, as well as upon the gap between the pieces welded. The presence of the gap in excess of 0.5 mm may cause flowing of the molten metal into the gap, and may lead, as a consequence, to production of a defective joint. In the cases where the gaps between the pieces joined were not in excess of 0.5 mm, shear tests of specimens with a weld spot nugget diameter of 7–9 mm showed that a fracture force was $\frac{19,000\text{–}32,000}{27,000}$ N, which is enough to provide sufficient performance of a spot joint.

Therefore, the high-quality spot joints are provided by regulating parameters of the welding cycles in ASW of the sheet metal in a vertical position. The joints can find application in manufacture of frame structures of modern freight and passenger cars.

1. Voropaj, N.M. (2004) Specifics of arc spot shielded-gas welding processes (Review). *The Paton Welding J.*, **7**, 26–31.
2. Potapievsky, A.G. (2007) *Gas-shielded metal arc welding*. Pt 1: Active-gas welding. Kiev: Ekotekhnologiya.
3. Tereshchenko, V.I., Sharovolsky, A.N., Sidorenko, K.A. et al. (1983) Peculiarities of consumable-electrode arc spot $CO_2$-welding. *Avtomatich. Svarka*, **9**, 51–53.
4. Asnis, A.E., Andrushchenko, S.V., Yushkevich, Z.V. (1986) Influence of stressed state on corrosion resistance of arc spot welded joints. *Ibid*., **8**, 1–3.
5. Tkachenko, A.N., Voskresensky, A.S. (2005) Application of arc spot welding in fabrication of car bodies. *The Paton Welding J.*, **12**, 22–24.
6. Tatarinov, V.S., Tereshchenko, V.I., Iorsh, E.T. et al. (1986) Corrosion fatigue resistance of overlap joints made by arc spot welding. *Avtomatich. Svarka*, **7**, 46–48.
7. Krylov, S.V., Asnis, A.E. (1983) Increase in impact strength of arc spot welded joints. *Ibid*., **7**, 17–18, 34.
8. *GOST 14776–79*: Arc welding. Spot welded joints. Main types, structural elements and sizes. Introd. 01.07.80.