NEW CAPABILITIES OF MECHANIZED ARC SPOT WELDING USING PULSE EFFECTS

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The issues related to producing of spot joints of structures on vertical plane using mechanized equipment for arc shielded-gas welding were considered. It was established that application of pulse electrode wire feed with controllable parameters allows essential simplification of process of producing welded joint, providing its necessary quality and repeatability of results. The prospects of application of this welding method were shown including also those with application of welding current sources with pulse algorithms of operation synchronized with pulse electrode wire feed.

Keywords: *arc spot welding, electrode wire, feed, pulse, control, formation, repeatability, equipment*

The mechanized and automatic arc welding using consumable electrode in carbon dioxide atmosphere found wide application due to the complete complex of favorable properties: simplicity, availability of materials, reducing of works terms and costs for structure manufacture, possibility to conduct process in different spatial positions, etc. The most frequent application has the process with natural periodic short circuits of arc gap and electrode metal transfer. In this case the quality of welded joint, economic characteristics of the process significantly depend on stability of electrode metal drops transfer [1].

The basic methods of electrode metal transfer stabilization are [2]:

- selection of optimal parameters of welding process and their stabilization;
- application of activated electrode wires;
- application of pulse-arc process;
- development and application of pulse methods of electrode wire feed.

The pulse electrode wire feed with adjustable parameters of pulsed movement (frequency, relative pulse duration, acceleration) is one of the most effective methods of stabilization of electrode metal transfer characteristics with a number of additional effects [3]. In particular, it relates to welding using thin electrode wires in CO_2. Nowadays there is enough information about significant influence of pulse feeding on quality of welded joint produced in different spatial positions [4–6]. However these data relate to welding at different conditions of welds of different length. It is important also to give a prospective evaluation of influence of pulse electrode wire feed on the process of arc spot welding (ASW) which is the aim of present work.

The ASW process is an effective method for joining of sheet structures with elements of frame during lining, for example, railway cars, small ships, other transport vehicles and objects of the kind.

During ASW in flat position it is not difficult in most cases to produce the quality spot joint. In welding on the vertical plane it is far more difficult to produce a spot joint, in particular, if sheets of more than 1 mm thickness are welded.

In the work [4] the algorithm of producing a spot joint in vertical plane using ASW in CO_2 was proposed, the principle of which consists in dividing the welding process cycle into several stages. At the beginning of the cycle the burnout of lining sheet at increased values of current and voltage is performed. Then, the obtained space is filled with electrode metal and base metal to which lining is welded on. The problems arise namely during filling the space of burnout.

The basic difficulties and occurring defects during making of a spot joint consist in instability of repeatability of a shape of a spot joint; distortion of lining sheet; overlaps and even metal flows (Figure 1); lack of penetration of base metal, sufficient to provide strength characteristics.

According to carried out investigations the causes for unsatisfactory quality of a spot joint produced using arc process are:

- instability of parameters of welding process (in particular, arc voltage), arising due to a number of natural reasons (changes of real electrode wire stickout, conditions of current supply in current-carrying tip);
- changes of electrode wire feed conditions resulting in incontrollable fluctuations of feed rate and consequently current, influencing the characteristics of fusion;
- heating of metal from performance of previous welded spot joints;
- lack of control of heat input into the pool of molten metal to produce a spot.

Mathematic model of ASW process presented in the work [7] allowed the evaluation of optimal parameters of heat input and also residual stresses after welding. The result of this evaluation appeared to be a development of the algorithm for selection of welding parameters of performance of arc spot joint including several cycles of synchronous change of current and voltage of arc process, i.e. the condition modulation. It allows performing control of heat input into a weld pool within some ranges and somewhat stabilize the process of producing a spot joint by selection of modulation parameters. However it is not always possible to find the complete solution for the problems connected with formation of a weld spot joint. Moreover, it is necessary to consider also the conditions of preparation of a structure for welding, first of all, providing surfaces being welded, tightly adjacent one to another. Here, a gap should be not only minimal, but also stable.

The great problem in welding with effective (deep) modulation of conditions is the periodical interruption of burning and exciting of welding arc, in this case the repeated arc excitement, as investigations showed, is not always stable due to formation of electrode metal drop of different size at the edge of a wire. As is seen from Figure 2, where different variants of a shape of a frozen drop are presented, only the shape of drop *3* and *4* allows reliable repeated arc exciting.

It is possible to exclude the basic factors of influence on formation of spot joint using methods of control of electrode metal transfer, in particular, controllable pulsed electrode wire feed. Figure 3 shows the testing-investigation stand for practicing of conditions for welding of spots in vertical plane. As a mechanism of pulse feeding, a new design of a gearless pulsed feeding mechanism based on a valve computerized electric drive with a wide range of control of parameters of pulsed movement of electrode wire such as pitch, frequency, relative pulse duration, shape [8] was used, in application of which a number of tasks on formation of welded joint with long welds as well as on energy- and resources-saving has been already solved until now [9].

It should be noted that the aims of control of electrode metal transfer at pulse electrode wire feed can be considered achieved in that case if the moment of electrode metal transfer corresponds to one pulse of feeding. In welding using thin wires Sv-08G2S in CO_2 (short arc welding) this transfer occurs at the moment of short circuiting of arc gap. In other types of controllable transfer the process is realized with considerable power consumption and should be solved by other complex of equipment combining pulse algorithms of welding current source and pulse mechanism of electrode wire feed.

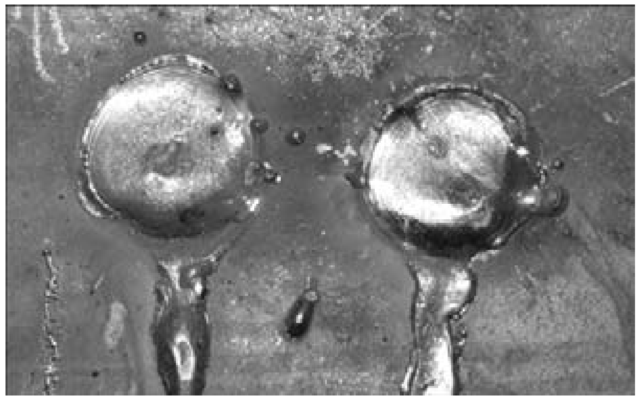

Figure 1. Appearance of spot during welding in the vertical plane with flowing out of molten metal and non-uniform formation of spot joint

The cycle of producing a spot joint can be largely split up into two stages: burnout of metal being welded on at the increased process conditions, and formation of a spot joint.

The second stage of spot joint welding was tested on the stand using pulse electrode wire feed. The purpose of experimental investigation was revealing the possibility of stabilization of making of a spot joint in vertical plane in this welding method. Here, one of the basic tasks to be solved was the determination of parameters of a pulsed feeding, the most sufficiently influencing the process and optimization of the most important characteristics of a spot joint, possibility of their multiple reproduction at minimal deviations in sizes and penetration.

For the work the combinations of steels St3 and 09G2S of 1.0 + 4.0 and 2.5 + 7.0 mm thickness, used in transport machine building, were used. The welding was performed using wire Sv-08G2S of 1.2 mm diameter with recommended consumptions of CO_2 under conditions: for joining of metals of thickness 1.0 + 4.0 mm the voltage of welding was 26–28 V, the average value of current for all investigated parameters of pulse feeding was 160 A; for joining of metals of thickness 2.5 + 7.0 mm the voltage of welding was 28–30 V, the average value of current was 200 A.

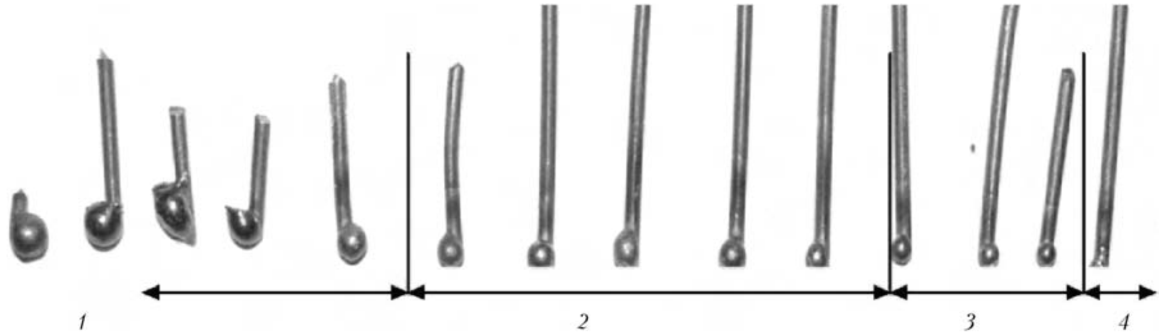

Figure 2. Appearance of electrode wire of 1.2 mm diameter with frozen drop at the moment of termination of arc burning: *1*, *2* — repeated excitement of arc is difficult; *3*, *4* — reliable ignition

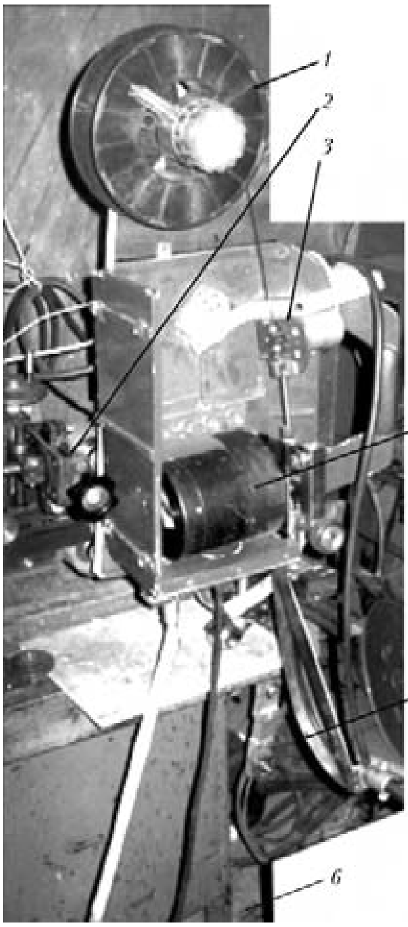

Figure 3. Stand for automatic welding of spots in the vertical plane with pulse electrode wire feed: *1* — cassette with electrode wire; *2* — mechanism of torch movement; *3* — sensor of wire feed rate; *4* — wire feed mechanism; *5* — torch for welding in the vertical plane; *6* — product

Figure 4 shows the «perfect» cycle pattern of a pulsed feeding. Basing on the gained experience of application of the pulse electrode wire feeding [10] the following adjustable parameters were used: frequency, relative pulse duration, pitch, rate of feed in pulse and in reverse of feed. In this case the relative pulse duration in accordance with designations in Figure 4 can be determined by the following relation:

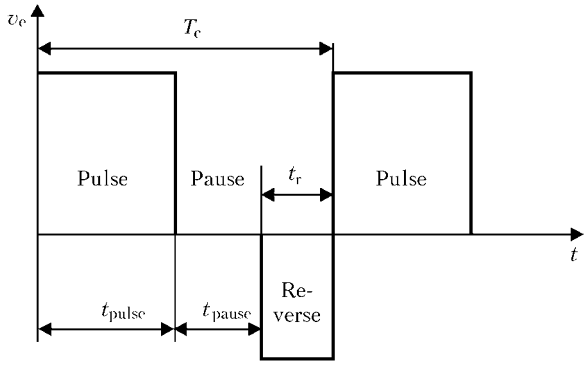

Figure 4. «Perfect» cyclogram of pulse feeding: v_e — feed rate; t_r, t_{pulse}, t_{pause} — time of action of reverse, pulse and pause, respectively; T_c — time of pulse feed cycle

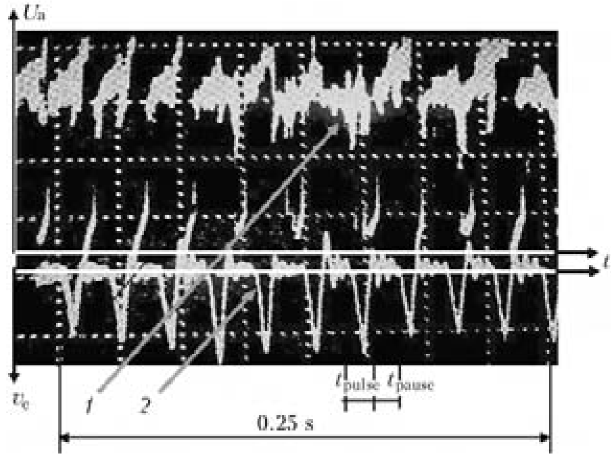

Figure 5. Oscillograms of welding process with frequency of pulse electrode wire feed of 40 Hz and relative pulse duration $S = 2$: *1* — U_a; *2* — v_e

$$S = T_c / t_{pulse}.$$

The influence of frequencies was investigated within the range of 1–10, 20–30 and 40–60 Hz. The experiments were carried out with relative pulse duration $S = 2$ and two variants of changes of a pulse feed of electrode wire: 50 % of time is pulse, 40 % — pause, 10 % — reverse, 50 % of time is pulse, 50 % — pause.

Figure 5 shows characteristic oscillogram with a pulse and pause of ASW process, performed in the vertical plane at frequency of a pulsed feeding of 40 Hz and relative pulse duration $S = 2$. The analysis of oscillograms evidences about high degree of stability of transfer process (one pulse of feed is one drop of electrode metal) and, consequently, about stability of the process as a whole.

At the frequencies in the range of 1–10 Hz it was not possible to obtain the process with formation of a weld spot, as the intensive spattering and leaks of metal from the molten pool were observed. At the frequencies of 20–30 Hz the welding process was more controllable, weld spot is formed, but rather intensive spattering of electrode metal and pool metal occurs. The most quality formation of weld spot was obtained at the frequencies in the range of 40–60 Hz, and at the frequency of 60 Hz the welding process has the best values with minimal (not more than 2–3 %) value of spattering. The result of this algorithm of functioning of controllable pulse feeding mechanism is a repeated number of spots without leaks of metal given in Figure 6. The spots of 12 mm diameter were obtained with a good appearance, deviations of not more than ±0.7 mm and stable guaranteed penetration of base metal providing the required mechanical properties of the welded joint (shear, tear strength, etc.). The destructing shear force for the thickness of specimens being joined 1.0 + 4.0 mm was 14,600–16,000 N, tear force — 12,450–14,700 N, diameter of nugget of weld spot was 5.2 mm; for thicknesses 2.5 + 7.0 mm the shear strength was within 16,900–22,000 N, tear

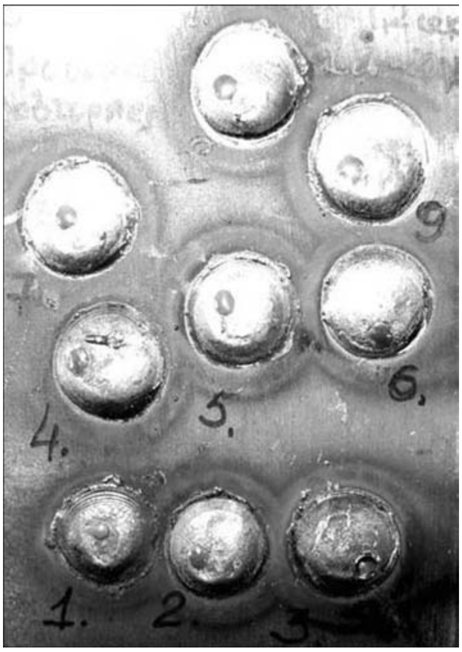

Figure 6. Appearance of spots produced by pulse electrode wire rate at 40 Hz frequency

strength — 15,000–20,000 N, diameter of weld spot nugget was 8.5 mm. Geometric sizes of spot joints meet the GOST 14776–79 («Arc welding. Spot welded joints. Main types, design elements and sizes»).

Unsatisfactory running of spot welding process at the frequencies of up to 20 Hz can be explained not by a value of frequency as itself, but by excessively large pitch of electrode wire feed, which is inevitable from the conditions of providing the preset integral feed rate and, consequently, by the average current of arc process which is provided by the new development of applied modern computerized valve electric drive.

The important condition for application of electrode wire pulsed feed is the repeated excitement of arc at technological interruption of the process (additional low-frequency control of heat inputs into the pool). This is possible at such form of a metal drop which is presented in Figure 2, pos. *3* and *4*.

It should be noted that in the process of work the levels of direct consumptions of electric power for conduction of welding process were recorded. Moreover, these consumptions were compared for the process with a conventional electrode wire feed at the same electrode wire consumption. It was determined that at the frequency of pulse feed of 40 Hz and $S = 2$ the direct saving of electric power is 15–20 %, and it is obvious that in these ranges the decrease of heat input into the pool of molten metal occurs, which is an important factor for this work.

The influence of parameters of a pulsed feeding on the formation of a welded joint and penetration can be evaluated on macrosections of a cross section of weld spots given in Figure 7.

The further investigations in this direction are connected with other ranges of thicknesses of material being welded, application of wider variety of parameters of a pulse feed and welding conditions basing on the methods of mathematical design of experiments.

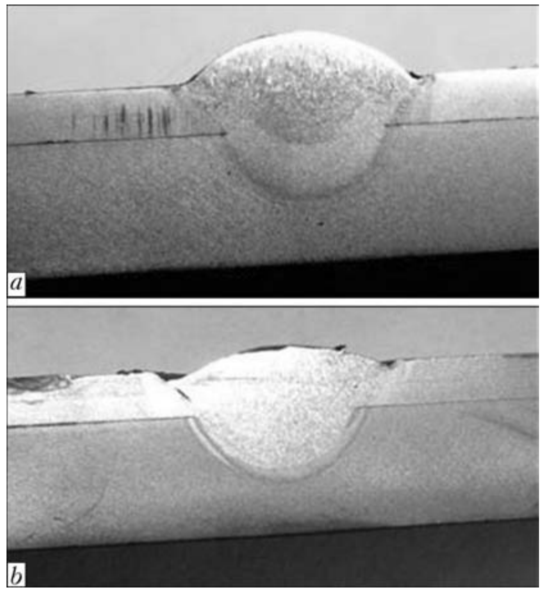

Figure 7. Transverse macrosection of spot of welded joint of sheets 2.5 + 7.0 mm thick at the frequency of pulse electrode wire feed of 60 (*a*) and 40 (*b*) Hz and relative pulse duration $S = 2$

The further modernization of ASW technology, including that in the vertical plane, is connected with new types of equipment and possibilities of producing combined pulse effects. In the work [11] the possibilities of influence on the arc mechanized welding process of a combined pulse effect from a pulse mechanism of electrode wire feed and pulse welding current source with pulse current components in output voltage on the process of arc mechanized welding were analyzed. Previously the technical realization of this welding method could not be completely realized as far as during design of equipment for this solution fulfillment several rather complicated problems arise, especially among them are control of parameters of pulses for effective influence on a molten drop and also establishment and maintaining of sequence of pulse coming from a feeding mechanism and source.

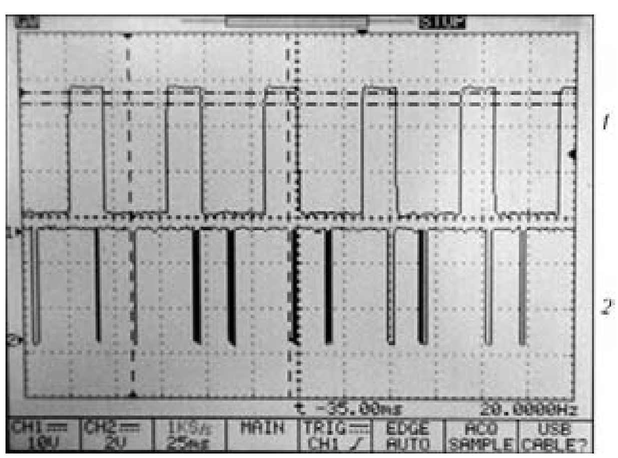

Figure 8. Oscillograms of synchronous formation of pulses of electrode wire feed mechanism (*1*) and welding current source (*2*) for combined effect on electrode metal transfer

The new types of gearless mechanisms of electrode wire feeding and modern welding current sources of inverter type with adjustable parameters of pulse effects, development of special software and a number of special technical means mentioned in this work allow solving these tasks providing new opportunities in welding.

In Figure 8 the oscillograms of pulse output effects from a feed mechanism and source are presented, algorithmically matched by parameters and phase shear relatively one another.

CONCLUSIONS

1. The producing of spot overlap joint using thin electrode wire in CO_2 is connected with a number of difficulties (unsatisfactory weld spot formation, flowing of base and electrode metals, low repeatability of results), predetermined both by possibilities of the process itself as well as difficulties of preparation of a structure for welding (pressing of sheets in the place of spot arrangement).

2. The pulse electrode wire feeding in CO_2 welding of steels by spots of overlap joints in the vertical has a significant influence on stabilization of the process, welded joint formation, its repeatability, considerably improving these characteristics of the process at optimally selected parameters of a pulse feeding.

3. The carried out investigations, proved by experimental verification, show that a method of producing weld spot joints with a pulse electrode wire feeding can be offered for application in industrial production of welded structures already at this stage and will be continued to study the range of conditions, parameters and combinations with other technological solutions.

4. The further modernization of ASW technology and also stabilization of electrode metal transfer is the combination of processes of a pulse electrode wire feed with a superposition of current pulses.

1. Potapievsky, A.G. (2007) *Consumable electrode gas-shielded welding*. Pt 1: Welding in active gases. 2nd ed. Kiev: Ekotekhnologiya.
2. Lebedev, V.A. (2010) Tendencies in development of mechanized welding with controlled transfer of electrode metal (Review). *The Paton Welding J.*, **10**, 37–44.
3. Lebedev, V.A., Gedrovich, A.I. (2010) *Technique and technology of arc welding and surfacing (nonstationary processes and operating conditions)*. Lugansk: Knowledge.
4. Lobanov, L.M., Timoshenko, A.N., Goncharov, P.V. (2009) Arc spot welding of overlap joints in vertical position. *The Paton Welding J.*, **1**, 26–28.
5. Pekoz, T., McGuire, W. (1980) Welding of sheet steel. In: *Proc. of 5th Int. Spec. Conf. on Cold-Formed Steel Structures* (St.-Louis, 1980).
6. Snow, G.L., Easterling, W.S. (2008) Strength of arc spot welds made in single and multiple steel sheets. In: *Proc. of 9th Int. Spec. Conf. on Cold-Formed Steel Structures* (St.-Louis, 2008).
7. Makhnenko, O.V., Timoshenko, A.N., Muzhichenko, A.F. et al. (2010) Improvement of the technology for arc spot welding of overlap joints based on the results of mathematical modeling. *The Paton Welding J.*, **11**, 21–26.
8. Lebedev, V.A., Rymsha, V.V., Radimov, I.N. (2009) Current valve electric drives in systems of mechanized welding equipment. *Elektromashynobud. ta Elektrooblad.*, Issue 74, 22–24.
9. Paton, B.E., Lebedev, V.A., Pichak, V.G. et al. (2002) Analysis of technical and technological possibilities of electrode wire pulsed feed in processes of arc welding and surfacing. *Svarochn. Proizvodstvo*, **2**, 24–31.
10. Lebedev, V.A. (2007) Peculiarities of welding of steels with pulsed feed of electrode wire. *Ibid.*, **8**, 30–35.
11. Paton, B.E., Lebedev, V.A., Mikitin, Ya.I. (2006) Method of combined control of electrode metal transfer in mechanized arc welding. *Ibid.*, **8**, 27–32.