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BRIDGING OF WELDING GAPS IN WELDING WITH A MULTIPLE-WIRE ELECTRODE

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An investigation on bridging larger welding gaps between workpieces occurring in practice due to structural requirements or to defects in weld edge preparation is described. Some characteristic cases from practice where a larger root gap should be bridged or the space between two or three workpieces should be filled with a greater quantity of filler material are described. Submerged-arc welding with twin-wire and triple-wire electrodes was applied.

Key words: *bridging, welding gap, weld root, twin arc, joint contact tube, multiple-wire electrode*

Premoštenje zazora pri zavarivanju s višežičanom elektrodom. Opisano je istraživanje premoštenja zazora između komada za zavarivanje, koji se u praksi pojavljuju zbog konstrukcijskih zahtijeva ili grešaka prilikom pripreme stranica šavova. Opisani su neki karakteristični primjeri iz prakse, gde je bilo potrebno širi zazor ili prostor između dva ili tri komada za zavarivanje premostiti pomoću veće količine dodatnog materiala. Upotrebljeno je zavarivanje pod prahom uz upotrebu dvostruke i trostruke žičane elektrode.

Ključne riječi: *premošćivanje, zazor vara, korijen vara, dvostruki električni luk, zajednička kontaktna vodilica, višežičana elektroda*

INTRODUCTION

In welding a root pass of a butt joint, the weld edge preparation is very important to perform high-quality welding. This particularly applies to automatic submerged arc welding with a twin wire or triple wire and for gas shielded arc welding where no transverse movement of the welding gun is possible. In welding of thin and medium thick plates, any tiny defect in the weld edge preparation, even up to 1 mm size, may be fatal. In practice, there are some nonstandard welded joints with uncommon welding gaps.

LITERATURE REVIEW

Bridging of welding gaps and filling up of larger welded joints occur in practice quite often, but they remain almost untreated in literature.

In spite of a quite detailed survey of journals and conference papers, only one article could be found in literature which explicitly reports on bridging of root gaps in submerged arc welding [1]. The author welded root passes between workpieces of 5 to 20 mm in thickness with gaps of 0 to 10 mm in width. As filler material for bridging gaps, he applied a wire with a diameter of 5 mm and, in addition to a shielding flux, also metal powder (∅ 1 mm). The investigations conducted led to a conclusion that in submerged arc welding with the metal powder addition, it is possible to bridge welding gaps twice as large as the wire diameter. It is, of course, necessary to weld with adequate welding parameters, particularly high arc voltage (40 - 48 V), i. e., with a long arc.

Welding of larger welded joints or of passes for which a greater quantity of filler material is required has been somewhat more often discussed in the literature. In the first group, there is welding with a strip electrode. In the literature there are some papers describing a successful application of submerged arc welding with a strip electrode, still the process has not been widely used in practice [2-6].

The second group of processes, with which bridging of welding gaps to a certain extent and especially increasing of melting rate and consequently easier filling of welding grooves can be achieved, consists of submerged-arc welding with additional metal powder [7-11].

The third group of processes, which permit bridging of welding gaps and make easier the making of filler passes, includes different submerged-arc welding processes with

J. Tušek, Faculty of Mechanical Engineering, Ljubljana, Slovenia

multiple wires. We are acquainted with processes, such as multiple-wire welding, multiple-head welding and welding with an additional hot and cold wire [12-16].

NONSTANDARD WELDING EDGES AND GAPS

Figure 1. shows eight nonstandard welded joints with uncommon welding gaps, which in some cases require even an asymmetrical weld. For each welded joint an ideal weld shape is indicated as well. This, however, can not be accomplished with a single-wire electrode or in a single run. An approximately ideal weld shape may be obtained by welding with a multiple-wire electrode, with a suitable arrangement of the wires in the joint contact tube.

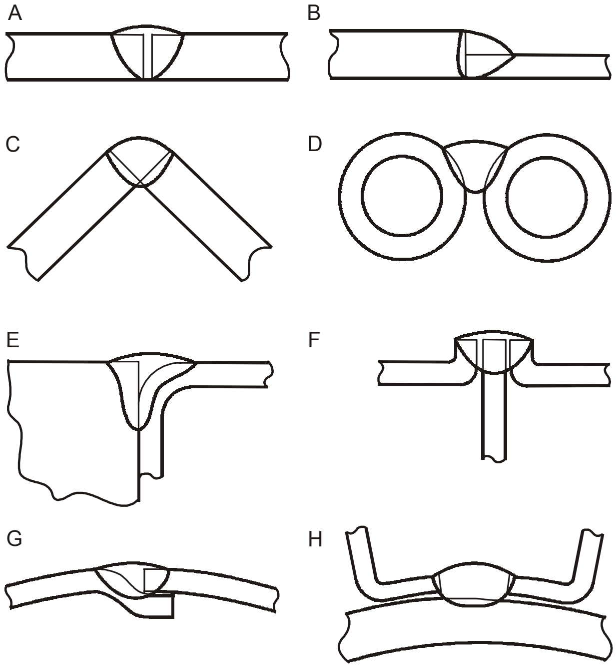

Figure 1. **Non-standard welded joints with uncommon welding gaps**
Slika 1. **Nenormirani zavari s neuobičajenim rasporom šavova**

In the first four cases (Figure 1. - A, B, C, D) a comparatively large welding gap could be bridged by welding with a twin-wire electrode. The wire arrangement in the contact tube should be parallel to the welding direction (Figure 2.).

The optimum wire diameter, distance between the wires and welding parameters should be selected in order to produce a uniform weld with a flat and smooth weld face.

Welds A, C, and D (Figure 1.) are symmetrical, which means that melting conditions in both arcs, if the twin-wire electrode was used, were the same. The wire extension lengths and the arc lengths were the same too.

Case B (Figure 1.) is somewhat specific. The arc lengths and the wire extension lengths of two wires were different (Figure 3.). Taking into account that the wire feed speeds of both wires and the currents in both wires were the same, it may be concluded that the electric resistance in the first arc was higher than in the second one. This means that the power of the first arc was higher than that of the second one and that a larger quantity of the parent metal was melted, which was very favourable in this case.

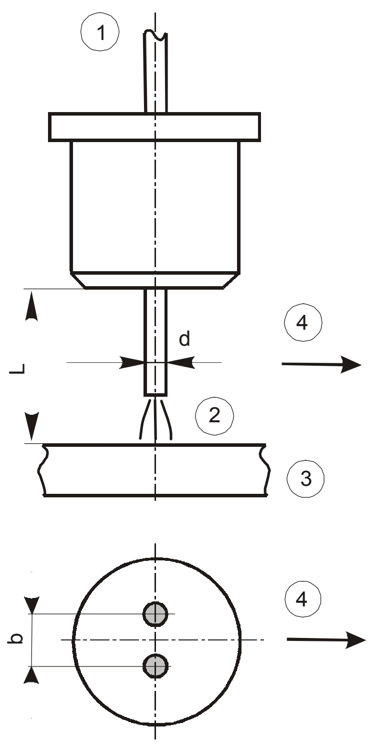

Figure 2. **Wire arrangement in the contact tube in welding with a twin-wire electrode: 1 - welding wire; 2 - arc; 3 workpiece; 4 - welding direction; *b* - distance between wires; *L* - electrode extension length; d_w - wire diameter**
Slika 2. **Raspored žica u kontaktnoj vodilici prilikom zavarivanja s dvostrukom žičanom elektrodom: 1 - žica za zavarivanje 2 - električni luk; 3 - radni komad; 4 - smjer zavarivanja; *b* - udaljenost između žica; *L* - dužina izvučenog (slobodnog) djela žice; d_w - promjer žice**

In cases E, F, H, and G (Figure 1.), the welds were welded with a triple-wire electrode. In three cases (F, G, H) a comparatively large welding gap with low penetration is required; therefore, the wire arrangement should be parallel in the welding direction (Figure 4.). The distance between the wires and the welding parameters should be selected so as to make a uniform weld with a smooth weld face.

In case E (Figure 1. E) an asymmetrical weld is to be made. This can be obtained by welding with a triple-wire electrode with triangular wire arrangement (Figure 5.).

The left workpiece (Figure 1. E) had a much higher mass than the right one, and consequently a stronger heat dissipation. Two wires were, therefore, travelling along the thicker workpiece, and only one wire along the thinner workpiece (Figure 7.).

WIRE ARRANGEMENT IN THE CONTACT TUBE

Because of the intricate shapes of the joint assemblies (Figure 1.), it is recommended to use two or three wires in a joint contact tube. The wires may be arranged in a line or in a triangular form in the case of three wires.

Figure 2. shows the contact tube with two wires. The wires were arranged parallel to reference to the welding direction and had the same wire feed speed, a joint power source, and a joint regulation. The distance between the wires was determined taking into account the welding parameters, the form of weld edge, and the diameter of the welding wire. The minimum distance was equal to 5 mm and the maximum one to 9 mm. In welding with greater distances between the wires, a uniform weld of high quality and nice shape was difficult to obtain. In welding with smaller distances, the welding gap was difficult to bridge and a much too narrow weld was obtained.

The welding parameters and the distance between the wires shall be chosen in such a way that a uniform cavity large enough to permit all the necessary metallurgical, chemical, and physical processes between the weld pool, slag, and gases.

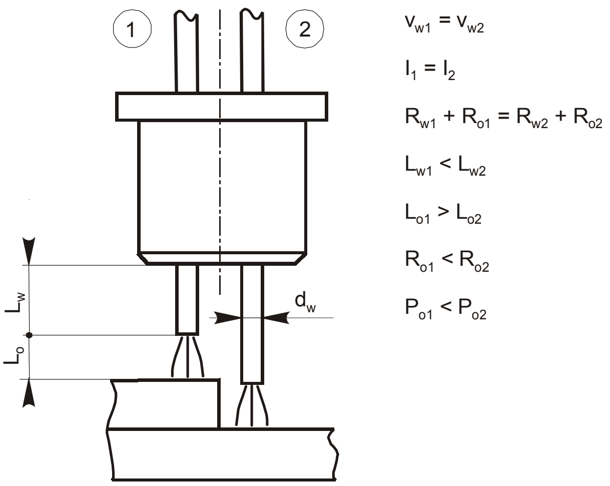

Figure 3. **Asymmetrical welded joint made with a twin-wire electrode: 1 - first wire; 2 - second wire; d_w - wire diameter; v_w - wire speed; I - current; R_w - electric resistance in wire; R_o - electric resistance in arc; L_w wire extension length; L_o - arc length; P_o - arc power**

Slika 3. **Nesimetričan zavar, zavaren pomoću dvostruke žičane elektrode: 1 - prva žica; 2 - druga žica; d_w - promjer žice; v_w - brzina žice; I - električna struja; R_w električni otpor u žici; R_o - električni otpor u luku; L_w - dužina izvučenog (slobodnog) djela žice; L_o - dužina električnog luka; P_o - jakost električnog luka**

In bridging of a welding gap of a lap joint or a butt joint composed of two different thicknesses (Figure 1. B), a twin wire can be used (Figure 3.). In this case too, the wires had the same wire feed speed and carry the same current. The resistance in the two wires being different, the arc lengths and arc powers were different, which affected the weld shape.

In welding of two or more workpieces using a large gap, three wires arranged in the line or in the triangular form can be used. The wire arrangement depends on the type of welded joint to be made. Figure 4. shows the contact tube

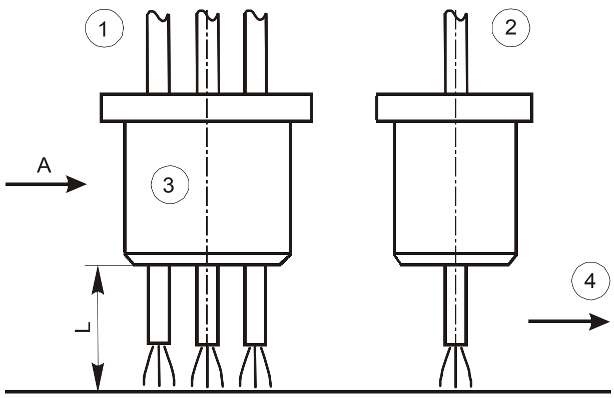

Figure 4. **Contact tube with parallel arrangement of three wires; 1 - welding wires; 2 - view A; 3 - contact tube; 4 - welding direction; L - wire extension length**

Slika 4. **Kontaktna vodica s tri usporedno postavljene žice; 1 - žice za zavarivanje; 2 - pogled A; 4 - smjer zavarivanja; L - dužina izvučenog djela žice**

with three wires arranged in the line and Figure 5. in the form of a triangle. In both cases (Figures 4. and 5.), the

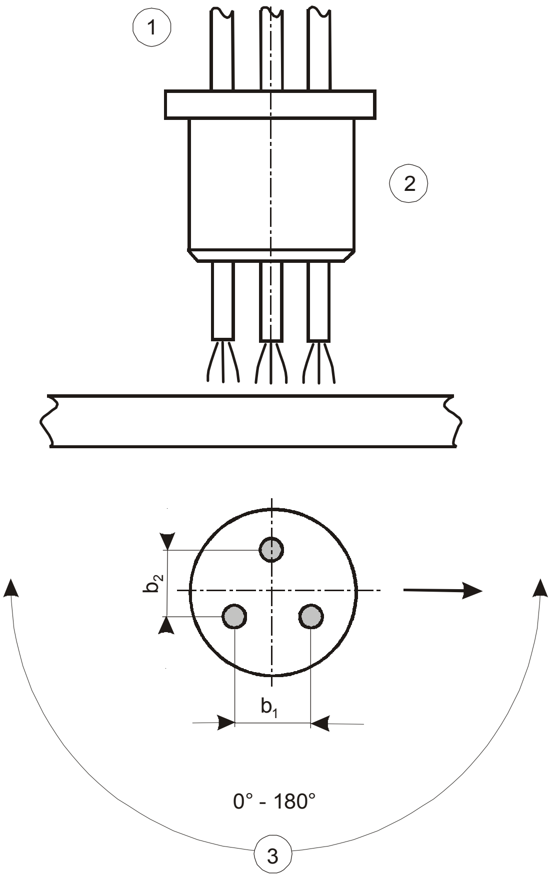

Figure 5. **Triangular wire arrangement for welding asymmetrical workpieces; b - distance between wires; 1 - welding wires; 2 - contact nozzle; 3 - possible welding direction**

Slika 5. **Raspored žica u obliku trokuta za zavarivanje nesimetričnih radnih komada; b - udaljenost između žica; 1 - žice za zavarivanje; 2 - kontaktna vođica; 3 - mogući smjer zavarivanja** wires had the same wire feed speed and a joint regulation, and a single power source was used. With reference to the welding direction, the line of wires can be arranged in the same direction, at a right angle, or at an angle ranging between 0 ° and 90 °. Figure 5. shows possible welding directions with reference to the wire arrangement for the device with three wires arranged in the form of a triangle.

MACRO SECTIONS OF THE WELDS

Figure 6. shows macro sections of root passes welded with the same parameters, the same distance between the wires, but with different sizes of welding gaps. The welding gaps were 0 mm, 2 mm, 3.5 mm, and 6 mm wide. There was no preparation of the welding edges.

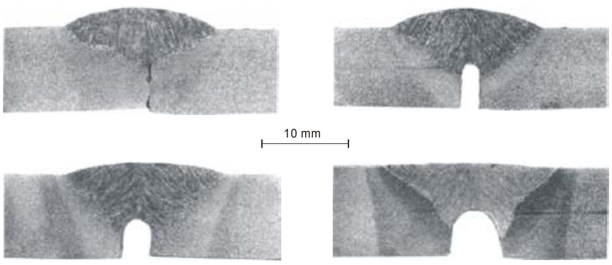

Figure 6. **Submerged arc welds made with a twin-wire electrode in various welding gaps: I = 2 x 200 A, U = 32 V, v_w = 0.5 m/min, d_w = 2 mm; workpiece thickness = 10 mm**

Slika 6. **Zavarivanje pod prahom s dvostrukom žičanom elektrodom u različitim zazorima šavova: I = 2 x 200 A, U = 32 V, v_w = 0.5 m/min, d_w = 2 mm; debljina radnog komada = 10 mm**

Regarding the fact that the welding parameters were constant during welding, the energy input in the filler material and the parent metal was constant too.

Consequently, the melting rate, i. e., the weight of the filler material melted in a unit of time, was constant as well. Because of a specific "direct" melting of the parent metal the quantity of the parent metal melted even slightly increased with an increase in the welding gap width.

The weld geometry changed as well with a change of the welding gap. The penetration depth increased, the weld reinforcement decreased whereas the penetration width practically did not change with the increase in the welding gap.

On the basis of the results obtained, the optimum distance between the wires was established. For plates of 10 mm in thickness and wires of 2 mm in diameter, this distance was equal to 7 mm. The optimum welding parameters depended not only on the wire diameter and workpiece thickness but also on the welding gap width and were in the range showed in Figure 3.

Figure 7. shows a welded joint (Figure 1. E) and the arrangement of three wires in welding with a triple-wire electrode. With the triple-wire electrode, the problem was solved ideally by welding the workpieces in a single pass.

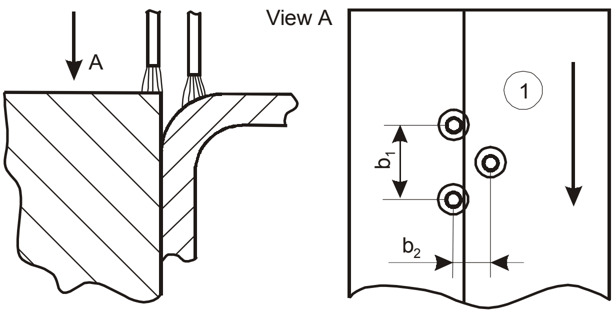

Figure 7. **Scheme of triple-wire electrode welding of two workpieces of different thickness and shape; *b* - distance between wires; 1 - welding direction**

Slika 7. **Shematski prikaz zavarivanja s trostrukom žičanom elektrodom dva različito debela i različito oblikovana radna komada; *b* - udaljenost između žica; 1 - smjer zavarivanja**

Two workpieces with different masses and of different shapes were welded together. In the thicker workpiece, dissipation of heat was much stronger than in the thinner one, therefore a risk of excessive penetration in the thinner workpiece and a too small penetration depth in the thicker one occurred. With a single-wire electrode, the workpieces shown can be multi-pass welded.

Two wires, together with the arcs, travel one after another over the thicker workpiece, introduce into it more energy and melt it. In this way, a penetration deep enough can be obtained on the thicker workpiece. Over the thinner workpiece, only one wire travels, introduces into it less energy which, with satisfactory penetration depth, causes less deformation. With an adequate choice of the distances between wires b_1 and b_2 (Figure 7.), a uniform, asymmetric weld with a nice weld face was obtained. Welding is carried out with a relatively high welding speed and a low energy input. The macro section of the relevant welds is shown in Figure 8.

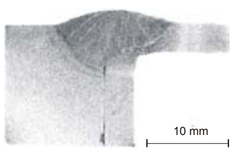

Figure 8. **Macrosection of an asymmetrical weld. I = 3 x 260 A, U = 29 V, v_w = 0.7 m/min, d_w = 2 mm**

Slika 8. **Makrografska epruveta nesimetričnog zavara; I = 3x260 A, U = 29 V, v_w = 0.7 m/min, d_w = 2**

CONCLUSIONS

With the investigation presented in the present paper it was established very clearly that welding gaps and welding edges can be bridged and multiple-wire welded with different number of wires and a different arrangement of the wires in the joint contact tube.

Conclusions can be summarised as follows:

1. The weld geometry is influenced mostly by the wire arrangement in the contact tube;
2. The most satisfactory results of bridging root gaps can be obtained in twin-wire electrode welding when the

wires are arranged in the direction transverse to the direction of welding;

3. In triple-wire electrode welding, larger gaps can be "filled" in a single pass;
4. With the triangular wire arrangement, asymmetric welds can be obtained, which is very favourable in welding of workpieces of different masses and shapes;
5. Multiple-wire welding shows higher energy efficiency; the energy input in the weld per unit volume is lower.

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