Consumable Guide Welding

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The development of the consumable guide technique in electroslag welding—the wire guide itself melts progressively into the weld pool—makes possible the welding by this process of a wide variety of joint configurations. The use of static, as opposed to sliding, shoes enables joints to be made satisfactorily between plates of unequal thickness. Investigations are described and some applications discussed in this article.

The welding of heavy steel plate by the manual arc welding process is a long and laborious operation requiring the deposition of many runs of weld metal together with deslagging and back-chipping and can be very costly in manpower. When welding in the downhand position, where automatic welding can be employed and high heat inputs tolerated, time and labour can be substantially reduced by use of processes such as the submerged arc and other techniques giving a high rate of deposition. Until the advent of the electroslag process however no technique was available to simplify the production of vertical welds.

Conventional Electroslag Welding with Wires

In recent years the conventional electroslag welding process has enabled welding in the vertical position to be carried out automatically with a high rate of deposition so that butt joints in thick mild steel plates can be made in one pass at rates of about 3 ft/hr. With this process a flame-cut square edge preparation may be used and fusion is achieved by the heat developed by resistive heating across a pool of molten slag which rises slowly up the joint as welding proceeds. The high heating current passes into the molten slag pool from a consumable wire continually being fed from above. The wire melts off in the slag and molten drops of steel are projected down to the solidifying weld pool which bridges the full width of the gap between the plates. The molten metal and slag are held in the weld gap by means of two water cooled copper shoes one on either side of the weld joint. These fit closely to the plate surfaces and, together with the wire feeding mechanism situated over the molten zone, slide up the plate at the speed of welding. The power supply can be either a.c. or d.c. and current is supplied to the consumable wire electrode as it is fed, by a wire feed guide. This enters the weld gap from one side and maintains a constant distance from the slag pool surface, so that electrode stick-out length does not vary appreciably.

Once a stable thermal condition has been established, welding proceeds smoothly and steadily, requiring only the occasional addition of some granulated flux to replace small losses of slag on the solidified bead surface.

By the use of such equipment it is possible to make vertical welds many feet high and in plate several inches thick, depending on the number of feed wires used and the capacity of the power source.

The Use of Consumable Guides

There are many cases however where welds in the vertical or near vertical planes have to be made between plates which are only a few inches thick and up to 4 ft. high.

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A large investment in capital equipment may not always be justified for such small 'jobbing' joints, and in particular it might not be convenient to bring such components to within the working area of the welding machine. Alternatively the joint may be difficult to make with a conventional machine when, for instance, accessibility is restricted on one side of the joint, as in welding the flanges on flanged girders or when plates being welded are not sufficiently matching in thickness or are perhaps bent so that the sliding shoes will not fit closely enough to the plate.

The welding of steel plates of up to 3 ft. long and 2—3 in. thick to end beams of mechanical test rigs has been carried out at BWRA very successfully for the past few years using conventional electroslag welders, and has been found extremely successful in reducing the time required for this work. Recently however, there has been a considerable increase in the number of test pieces needed together with a requirement for welding 2 in. plate to 3 in. plate and 1 in. plate to 2 in. plate, joints not easy to make on conventional electroslag welding machines. Because of this increasing demand for the use of the process, the possibility of using the consumable guide technique has been examined and the preliminary results which may be of interest to many of our members are reported below.

In the consumable guide technique, fixed shoes are used and the electrode wire is fed to the slag pool surface through a steel tube or composite plate which melts off into the rising slag bath. The consumable guide is clamped rigidly into the weld gap and must not touch the sides since it is through the guide that power is supplied to the wire.

With this system the elaborate mechanism for climbing the weld are avoided, and only a power source, wire feed unit and set of shoes are required. It also has the advantage that joints of complex shape and materials of varying thickness may be welded with comparative ease.

Butt Joints Made with Consumable Guides

Vertical butt joints have been made between materials from 1—3 in. thick. The guides have in all cases been steel tubes with a $\frac{5}{8}$ in. O.D. and a 3/16 in. bore and 2% Mn welding wire of 1/8 in. diameter has been used throughout.

An alternating current power source with a fairly flat characteristic was used throughout and current and voltage measurements were often made during the course of welding. The fluctuations in current

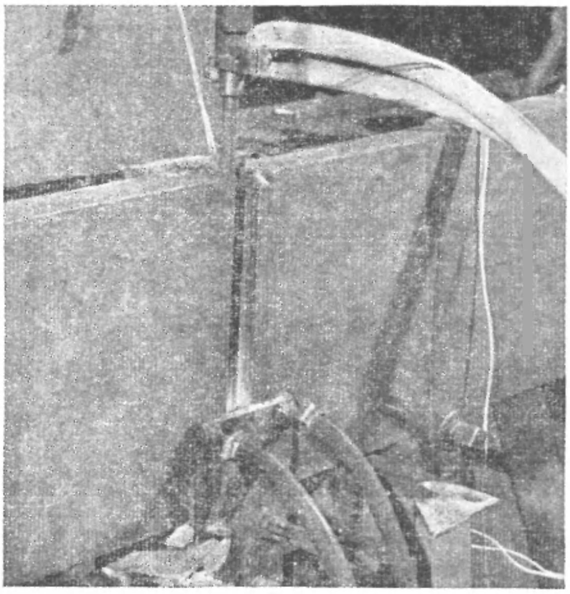

Fig. 1. A single consumable guide weld being made between 2 in. thick low alloy steel plates.

when using a consumable guide tend to be greater than for wire welding and this is thought to be due to the spasmodic melting away of the guide tube. Figure 1 shows a vertical butt joint being made between two plates 2 in. thick using clamped shoes and a single consumable guide. When the slag level had nearly reached the top of this shoe a second shoe was placed above the first. For longer joints the two shoes would have continued to overtake each other until the weld was completed. A single long shoe was used at the other side of the joint.

The power leads can be seen attached to the top of the consumable guide tube, the earth return being fixed to the base of one of the plates.

The consumable guide welds were started by placing a small ball of wire wool under the wire electrode tip protruding from the guide tube and a small amount of granulated flux on top of the wire wool, see Fig. 2a. A higher voltage was used for starting the welds, when the wire wool and flux melted to establish layers of molten metal and slag. After this initial melting welding proceeded smoothly.

Figure 2b shows the joint between a 3 in. thick piece of Ducol W30 and a 2 in. thick piece of BS.968 plate, and illustrates the suitability of the process for joining materials of different thickness. Strong magnets were found to be a simple and efficient method of holding the shoes in position. The degree of penetration and fusion of the two parent plates can be seen in the macrosection of this weld shown in Fig. 2c.

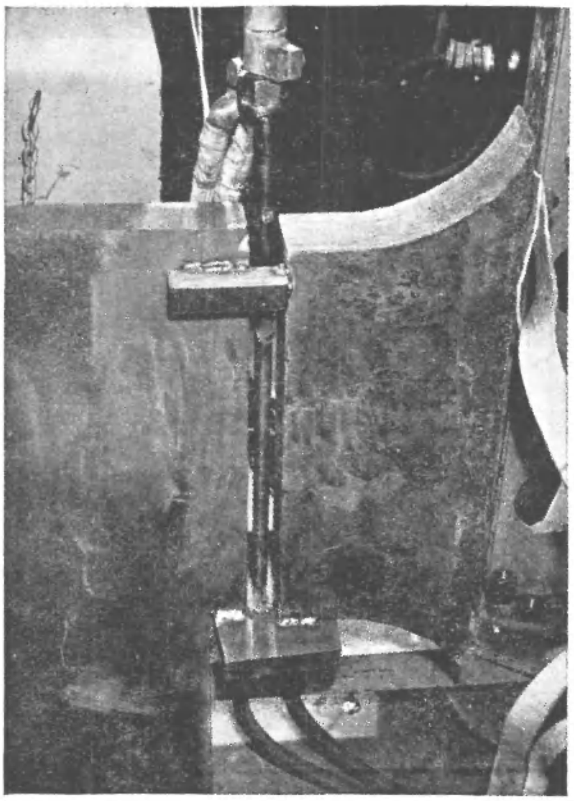

Fig. 2a. Butt joint between 3 in. thick Ducol W.30 and 2 in. thick B.S. 968 before welding, showing wire wool insert used for starting.

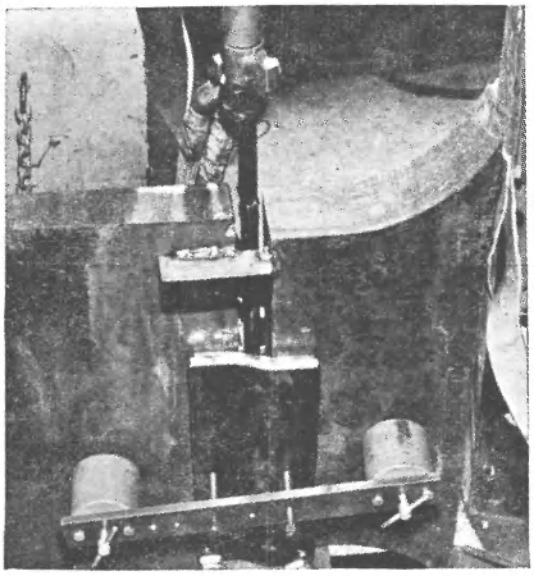

Fig. 2b. With the shaped shoes held in position.

These welds required only one consumable guide, see Table. However, when 3 in. thick plates were welded it was found necessary to use two consumable guide tubes to achieve proper fusion and penetration.

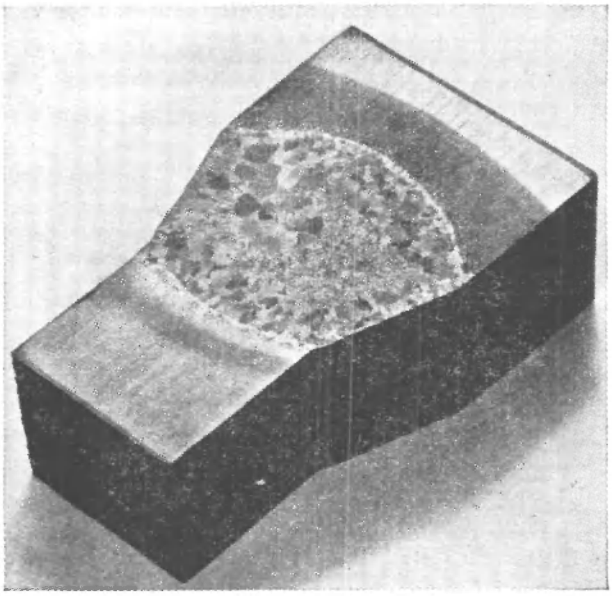

Fig. 2c. Macrosection of the finished weld.

Figure 3 shows the macrostructure of a vertical butt weld in 3 in. thick plate made with two consumable guides. The welding conditions used are given in the Table.

The welding speed on all these butt joints amounted to between 3 and 5 ft/hr.

Welding of Alloy Steels

In the past the use of electroslag welding has been largely confined to welding of mild steel plate, but some fabricators have begun to use the process on

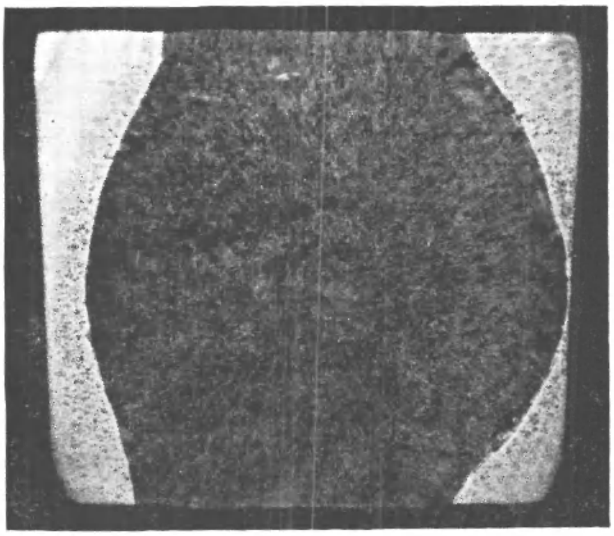

Fig. 3. Macrosection of a doubleguide butt weld between 3 in. thick plates in which the weld metal was alloyed with nickel chromium and molybdenum.

steels of higher strengths and the need to develop weld metals containing alloying elements such as nickel, chromium, manganese and molybdenum to give matching strengths leads to a consideration of the consumable guide as a possible means of alloying. In fact the amount of alloying element that can be added by means of the guide is very limited, but an experimental alloy weld metal has been successfully made at BWRA by welding strips of Nimonic alloys and a 13% chromium steel to the edges of the plates before welding, see Fig. 3. By this means, weld metal ultimate tensile strengths of 50—60 tons/in² and Charpy impact values between 20—40 ft/lb at room temperature have been measured. The technique will need considerable further investigation, however, before it can be recommended for production welds.

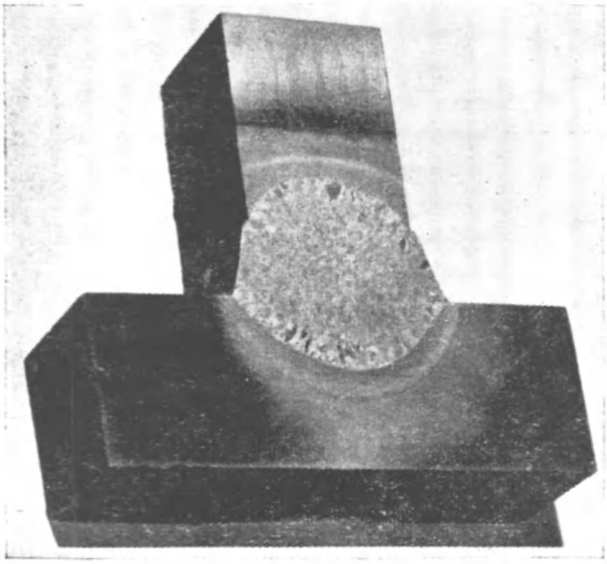

Fig. 4. A Tee-Butt weld between 3 in. thick plates made with two consumable guides.

Welding of More Complex Joints

The success and versatility of the consumable guide process depends largely on the availability of the containing shoes. Shoes have been made to fit various joint configurations and this has enabled Tee-Butt welds between materials of various thickness to be made with good penetration at welding speeds of nearly 5 ft/hr. see Fig. 4. The values of current and voltage found to be satisfactory for a number of these joints are given in the Table.

A more complex joint in the form of a cross has been made between four plates each 2 in. thick, see Fig. 5. The water cooled copper shoes for this joint were made from 1¼ in. square bar on which the desired weld reinforcement shape was cut, and the water holes were drilled out to give a minimum wall thickness between the water passage and the molten slag of

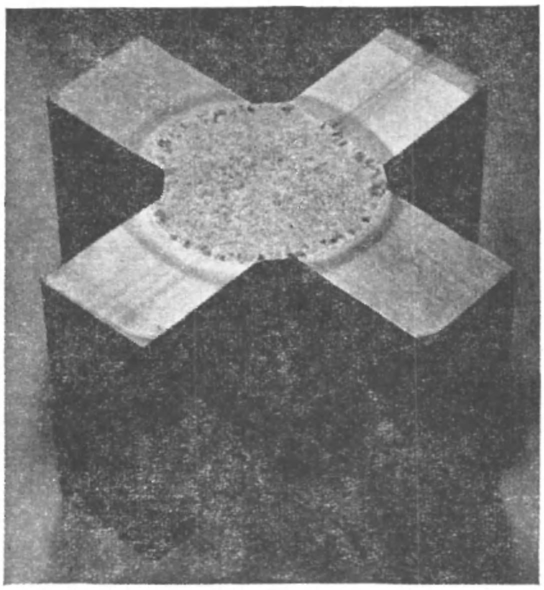

Fig. 5. Macrosection of the cross weld between 2 in. thick plates, for which two consumables guides were used.

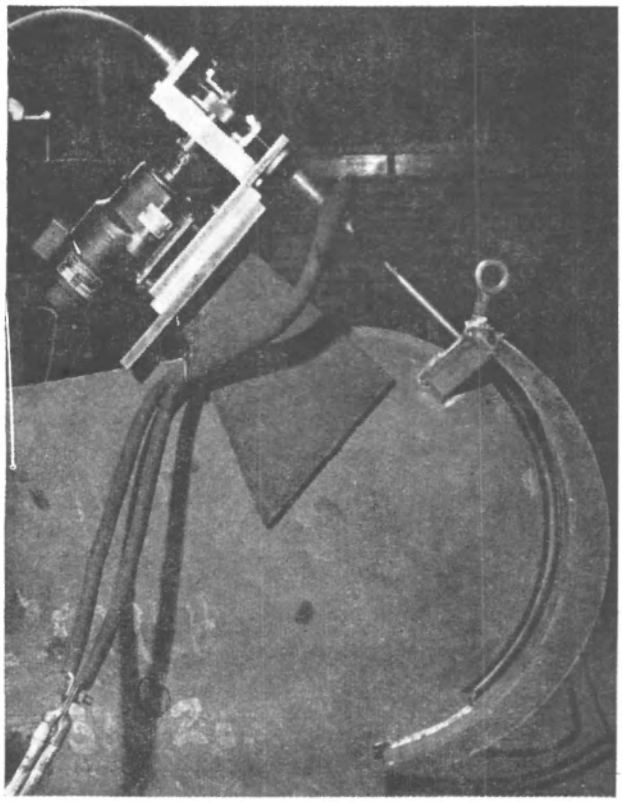

Fig. 6. Curved Tee-Butt test weld on manipulator prior to welding.

5/16 in. The plates were made to overlap to some extent for ease of fit up, so that the weld gap measured 2×1¼ in. By using two guide tubes, a votage of 40 V and a total current of 1200 A, the heat input was sufficient to melt through the four corners enabling the metal to solidify against the copper shoes with a smooth and even profile.

The feasibility of using the consumable guide process for making other than straight vertical welds has been proved on a curved Tee-Butt weld, see Fig. 6, 7 and 8.

The joint made was circular about a radius of 16 in. and extended through an angle of 90°. The Tee-Butt stem plate was 2 in. thick B.S.968 and the curved flange Ducol W30. Special copper shoes were made for this joint from 3 in. square bar and cold formed to the desired shape. The consumable guide tube was shaped to lie at the centre of the weld gap and in case of any tendency to distort during welding, wedges of insulating material were inserted to hold the guide in place. The whole test piece was mounted on a manipulator and slowly rotated during welding so that the slag pool remained perpendicular to the sides of the plates. The wire feed unit was mounted on top of the plate of BS.968, as shown in Fig. 6 and 7.

It is envisaged that welds of this kind could have possible applications in the manufacture of large press frames and possibly in boiler construction. Further experimental work will aim at widening the scope of the technique and determining more precisely the rela-

Table of Consumable Guide Welding Conditions

Type of weld joint	*Area of weld gap*	*Voltage V*	*Current A*	*No. of guides*
Butt 2×2 in.	2×1¼ in.	36	600	1
But 3×3 in.	3×1¼ in.	40	600	1
Butt 2½×2½ in.	2½×1¼ in.	40	600	1
Butt 3×3 in.	3×1¼ in.	36	1200	2
Tee-Butt 2×2 in.	2×1¼ in.	35	600	1
Tee-Butt 3×2 in.	2×1¼ in.	36	600	1
Tee-Butt 3×3 in.	3×1¼ in.	40	1200	2
Butt 3×2 in.	1¼ in. gap	35	1200	2
But 2×1 in.	1¼ in. gap	35	600	1
Cross weld 2×2×2×2 in.	2×1¼ in.	40	1200	2
Curved Tee-Butt 2×2¼ in.	2×1¼ in.	35	600	1

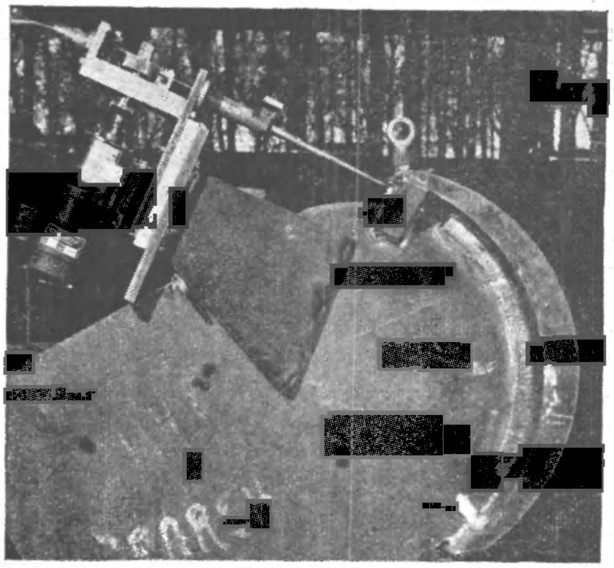

Fig. 7. The completed Curved Tee-Butt weld after removal of the shoes and slag.

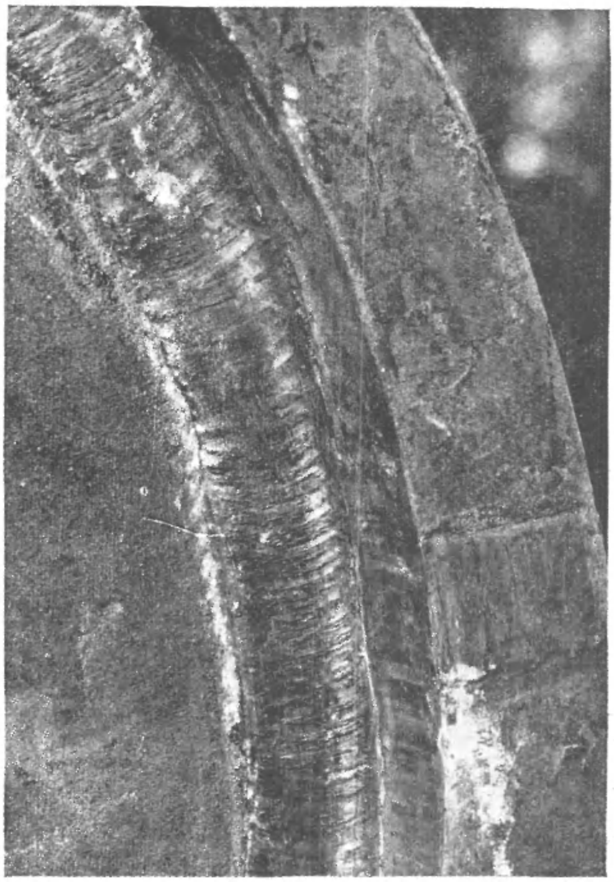

Fig. 8. Detail of the Curved Tee-Butt weld.

tive importance of a number of welding variables so that higher welding speeds and even better quality welds can be made.