Situation of Research in Electroslag Welding—A Tendency of Further Development

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Introduction

The desire to achieve maximum productivity when welding thick components—10 to 2,000 mm—led to the development of the mechanical electroslag welding processes, which enable vertical plates to be joined in one or several passes.

Welding of low-alloy steel components by the electroslag processes has in the past been restricted to special applications of vessel, ship and heavy machinery construction, due mainly to the low toughness of the joints in the as-welded condition. In many cases the specified minimum toughness requirements of components in the as-welded condition could not be achieved. By appropriate post weld heat treatment, it is generally possible to improve the notch toughness values of the weld metal and the HAZ to such an extent that they satisfy these requirements. However, in many cases such a heat treatment is quite impracticable or uneconomic. Projects have, therefore, been initiated with a view to developing these types of processes for welding low-alloy steel components which would enable, on the one hand, improved productivity and on the other hand improved toughness characteristics of the joints in the as-welded condition by reducing the thermal cycle in both the weld pool and HAZ regions.

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Various techniques of electroslag-high speed welding

To improve the structure and the toughness of the welded joints in the as-welded condition it is necessary to increase the deposition rate and welding speed while at the same time reducing the energy input per unit length. This has the effect of increasing the heating and cooling rates and reducing the dwell times in the critical temperature range for rapid-grain growth. This improvement in the process efficiency and in the joint quality can be achieved by the use of high currents and the addition of metal powder/1-8/ to the molten pool, along with optimum electrode arrangement and joints geometry. The supply of the filler metal in powdered form and without electric current increases the rate of deposition and reduces overheating of the molten weld pool. In conjunction with increased nucleation such cooling of the molten pool affects the structure favourably. In addition the strength and toughness values of the weld metal are increased, thus enabling considerably faster welding speeds to be used.

For electroslag-high speed welding with metal powder additions, various electrode and metal powder feeding systems were developed for different plate thicknesses and different joint preparations, in order to ensure reliable welding and stable process conditions. The welding machines are powered by direct current having a flat characteristic. The wire electrodes are at a positive potential. With electroslag welding, use is made of a double wire electrode when welding square-butt joints between plates having a thickness from 10 to 40 mm (Fig. 1). In this case the two wires are placed side by side so that they can be located as close as possible to the plate edges to be welded. This is beneficial in preventing lack of fusion defects at the plate surfaces, bearing in mind the high welding speeds. The metal powder is supplied by argon gas from the front. The powder tube is at some distance from the copper contact tube and firmly joined to the latter. Owing to the electro-magnetic field the metal powder adheres to the wire electrodes, which positively convey it into the slag bath. So as to stabilise the metal powder supply at high welding currents, contact tubes were magnetically screened by means of U-shaped transformer stampings. This avoided arcs striking across the metal powder to the plate edges, and blocking of the feed tubes, such as might result from the large magnetic fields. The laminated transformer stampings deflect the magnetic fields, thus ensuring that the metal powder feed tube passes through a low-field region.

With plate thickness between 50 and 100 mm use is made of two double wire electrodes (Fig. 1), the separation of which can be adjusted in the gap, depending on the plate thickness. Unlike the previously described techniques/5/ the metal powder is not supplied from outside the gap to the front and rear wire electrode pairs, but from inside against the electrode pairs. It took magnetic screening of the contact tube pairs to enable this type of powder transport to be achieved, since in spite of the strong magnetic fields it ensured reliable delivery of the powder through the thin feed tubes at the centre of the plates.

The application of metal powder without electric current to the electrodes itself contributes greatly to reduced overheating of the molten pool. However, by introducing the powder at the centre of the plates the most intensively overheated part of the molten pool is cooled directly, thus further reducing any danger of hot crack formation. This is particularly advantageous, if no micro-alloying elements capable of leading to embrittlement of the weld metal after post weld heat treatment are introduced as nucleating agents in the wire or in the metal powder.

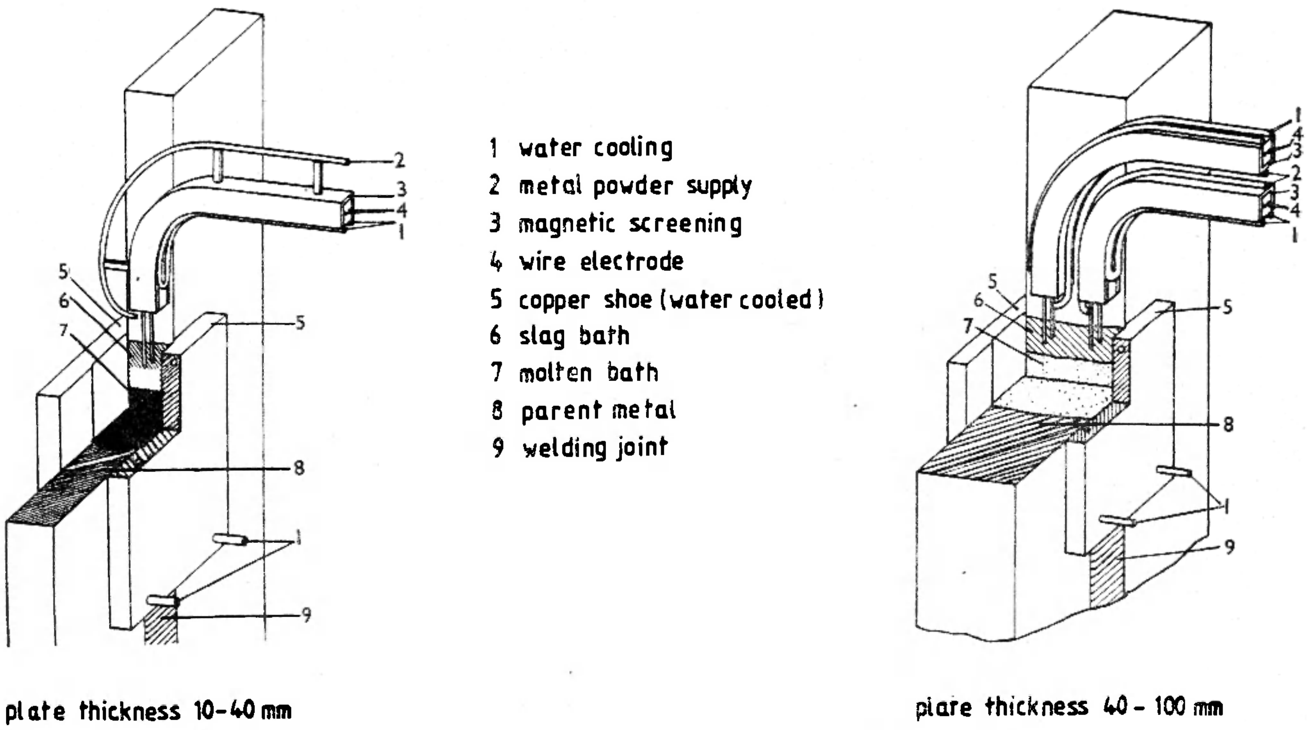


Fig. 1 Procedures of electroslag high speed welding with powdered filler metal when preparing square-butt joints.

The influence of welding technology on the structural shape and the notch impact energy of a structural steel is shown an Fig. 2. The steel quality St 52-3, thickness 63.5 mm, was welded conventionally with two wire electrodes, θ 3.0 mm, a welding voltage of 31.5 V and a total current of 1000 A and a welding speed of 1.6 m/h. The high speed welding was made with two double wire electrodes, θ 3.0 mm, a welding voltage of 51 V and a total current of 2600 A and a welding speed of 13.9 m/h. The quantity of metal powder transferred was 120%.

In order to reduce the volume of the molten pool, thus further increasing the welding speed and reducing the energy input per unit length, attention can be paid to joint preparation. Welding 38 mm steel plates a double V-butt joint is assembled with an included angle of 45° to 50°, using manual metal arc tack welding. When preparing double V-butt joints according to the pass/capping pass method it has proved advisable to make use of two wire electrodes arranged in tandem (Fig. 3)/4/. The metal powder can be applied both to the front and rear electrodes. The flux is supplied continuously passing from behind the electrodes into the slag bath. With this techniques the copper contact tube and the metal powder feeding tubes are screened by means of transformer stamping too so as to ensure absolutely smooth and reliable powder delivery.

Fig. 4 shows the ways in which the metal powder supplied without electric current affects the penetration profile and the primary structure. With square butt joint preparation as well as by lowering the amount of energy input and increasing the welding to 19.7 m/h (energy input : 240 kJ/cm) the width of the coarse grained zone amounts to as little as 1.5 mm and the width of the entire heat-aflected zone to 7 mm.

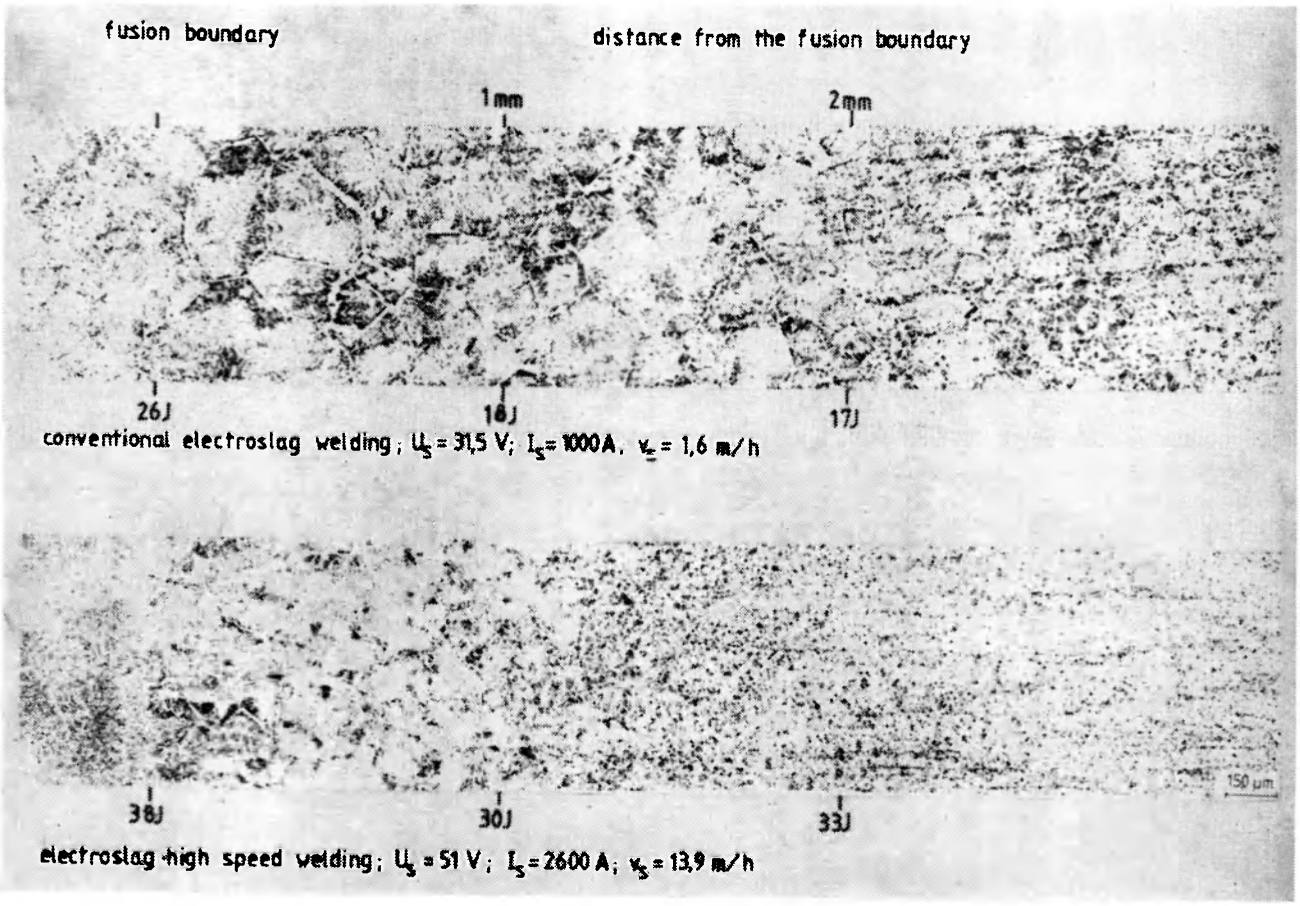
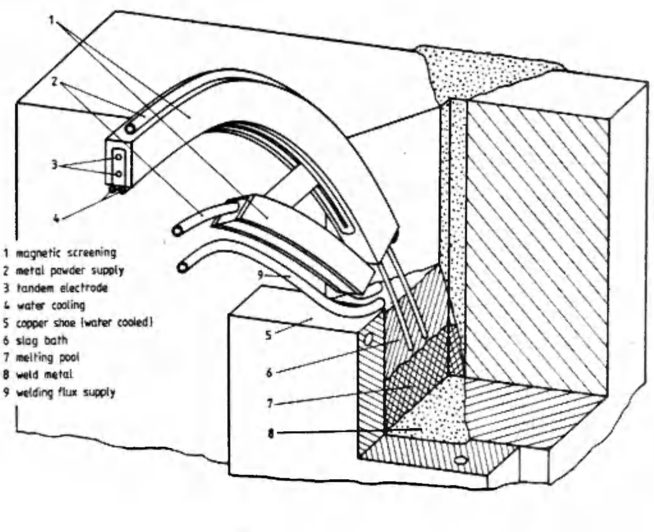


Fig. 2 Secondary structure and charpy impact results of electroslag welded joints for two welding methods in the as welded condition (parent metal : ST 52—3; 63,5 mm thick, Charpy-V : 273K)



electroslag highspeed welding

Fig 3. Procedure of electroslag high speed welding with powdered filler metal when preparing double V butt joints.

The considerable reduction of energy input per unit length and the increase of welding speed with the pass/capping pass method (60 kJ/cm, 36 m/h) results in the width of the coarsegrained zone being reduced to less than 1 mm.

With this increase of welding speed and the drastic reduction of energy input by appropriate joint preparation we do find on the one hand, the grains along the fusion boundary and at a distance of 1 mm are very much smaller than with the methods entailing square butt joints preparation while, on the other hand, the structure of the coarse-grained region in the HAZ is structurally modified. The wide ferrite bands at the grain boundaries are no longer present. In spite of the fact that coarse grains are still produced the structure consists only of bainite. At a distance of 2 mm, only the fine grained zone can be seen.

Prospect

The quality control of the weldments, however, must not only be guaranteed by various technological and metallurgical measures, but also by a better reproducibility of the process parameters with the aid of automation of the welding process.

Conditional on the special requirements, which the electroslag high speed process puts on the operator viz the need of automatic quality assurance and for improving the reproduction of the weld quality, it is desirable to mechanise the electroslag process more intensively (Fig. 5). The recording of the welding parameters is a great step on the way to automation. Before you can improve the process, it is necessary, to measure the essential parameters.

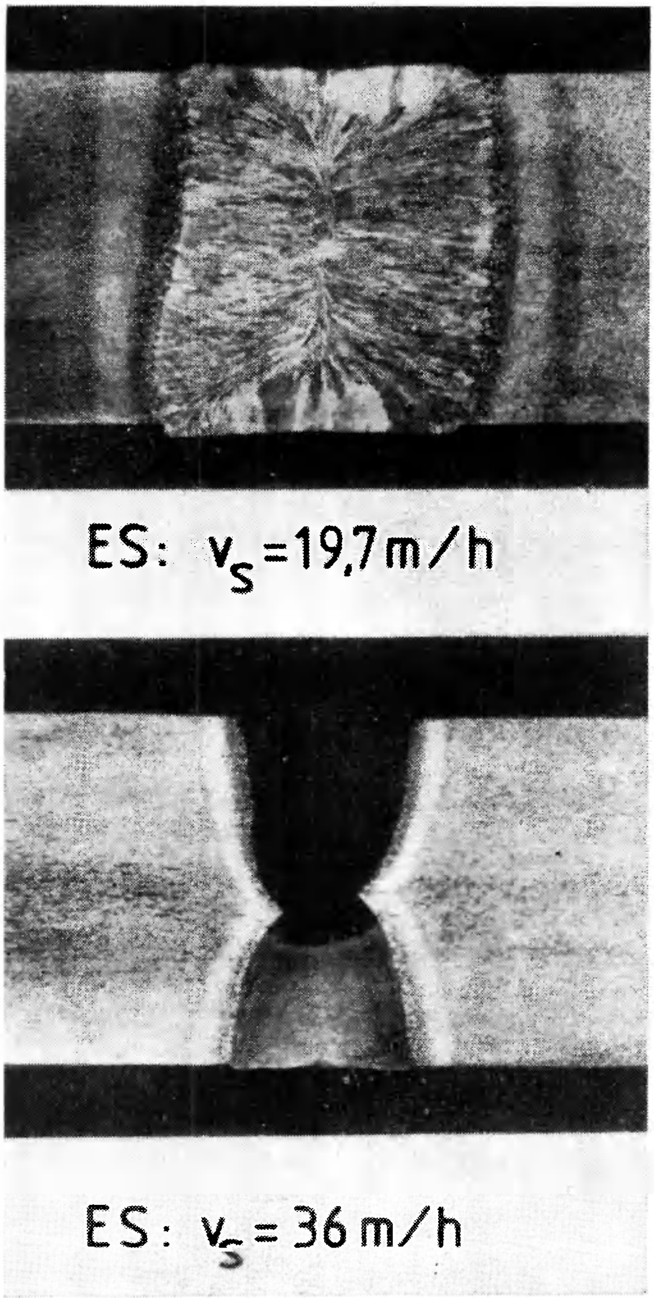
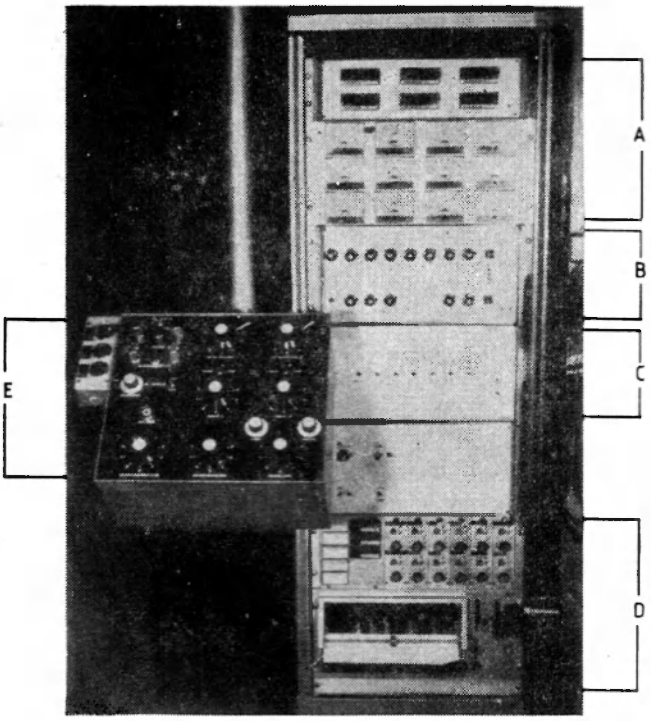


Fig 4. Preparation form and primary crystal line structure of electroslag-high speed welding (parent metal : 15 Mn Ni 63, 38 mm thick.)



A: measuring instruments
B: set value unit, automatic control unit
C: manual - automatic switching system
D: recording unit
E: remote control desk

Fig 5. Measuring aud recording unit with automatic control and remote control desk.

After building a measuring and recording unit an automatic control unit was developed going out from an analysis of the electroslag welding processes, which controls respectively the current, wire feed speed, metal powder supply and voltage automatically according to set values and keeps them constant. For controlling the welding speed a photooptical sensor was used, which scans the surface of the slag bath. Planned is the development of a fully automatic process, controlled by a micro computer.

Present investigations are engaged in the employment of electroslag-high speed welding techniques to join plates up to 350 mm thickness by using three double wire electrodes and oscillation of the nozzles.

References

1. E. Deleu, W. Soete, Gent, P. L. Threadgill, Abington Hall and B. Wubbels, Aachen—The fracture toughness and defect tolerance of electroslag welds DVS-Bericht Band 68, 1981, S. 1-11.

2. F. Eichhorn, P. Hirsch, W.-G. Burchard, H.-J. Klaar and B. Wubbels—ElektroschlackeschweiBen neu entwickelter uberhitzungsunempfindlicher Stahlwerkstoffe, SchweiBen und Schneiden 32 (1980), H. 11, S. 442-448.

3. F. Eichhorn, P. Hirsch und B. Wubbels—Use of metal powder additions to improve the strength and thoughness of high speed electroslag and electrogas welds in micro-alloyed and low alloy steels IIW-Doc. XII-J-76-80.

4. F. Eichhorn, P. Hirsch, H. W. Langenbahn und B. Wubbels—Untersuchungen zum Einsatz des Elektrogas—und Elektroschlackeschnellschwei Bens in Mehrlagentechnik zum Verbinden von Stahlblechen fur Reaktorsicherheitsbehalter DVS-Bericht Band 52, 1978, S. 168-172.

5. Ivochkin, I. I., A. I. Alekseev, A. F. Sosedov, B. F. Lebedev. V. I. Arramenko und I. M. Ivockhin—Electroslag Welding with Powdered Filler Metal Svar. Proiz. 1972, No. 5, S. 17-19.

6. Reynolds, G. H. und E. J. Kachelmeter—Adding powdered filler metal speeds deposition rate Metal Construction, September 1978, S. 426-432.

7. Shackleton, D. N.—Further Toughness Data on Electroslag Welds in C-Mn-Steels. The Welding Institute, Research Report, Oktober 1978.

8. F. Eichhorn und J. Remmel—Elektroschlacke-und ElektrogasschnellschweiBen an niedriglegierten Stahlwerkstoffen, DVS-Bericht Band 68, 1981, S. 1-11.