INCREASE OF RESISTANCE OF WELDS TO FORMATION OF CRYSTALLINE CRACKS IN REPAIR OF BANDS OF KILN FURNACES USING ELECTROSLAG WELDING

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The results of study of causes of appearance of crystalline cracks in central parts of layers of multi-layer electroslag weld are given. The method of increase of resistance of such welds to formation of crystalline cracks applied to repair of damaged bands of rotary kiln furnaces at the site of their operation is developed.

Keywords: *multi-layer electroslag welding, rotary furnaces, bands, carbon steels, crystalline cracks, repair, weakness area*

The most critical parts of rotary kiln furnaces are bearing bands of solid rectangular section, which are mounted on the furnace body with a definite radial gap, and bands of solid shaped section, welded-in into the furnace body [1]. The bands are manufactured of medium-carbon steels of the type 35L, 30GSL and 34L-ESh. The sizes of cross sections of butts being welded of bands are (355–500) × (900–1350) mm, outer diameter is up to 8450 mm.

Through cross cracks, often initiated in the bands of rotary furnaces during operation, result in forced and durable stop of the whole machine for replacement by a new band or repair of the band which came out of order [2].

In most cases the rewelding of cracks is performed without removing of a band from the furnace body. To realize this method of repair a band is set in a way that damaged place was positioned strictly in upper position by rotation of the furnace body. To repair the non-through cracks the groove is made using drilling of holes of 50 mm diameter with a pitch of 0.8–0.9 of diameter, and welding is performed using non-consumable nozzle with a feed of single wire of 5 mm diameter [3]. However due to the high rigidity of fastening of edges in re-welding of holes of the depth of more than 100 mm the crystalline cracks are formed in welds (Figure 1). Besides, the re-welding of through cracks is complicated by the requirements of limitation of residual deformations, distorting the initial geometric sizes of a band.

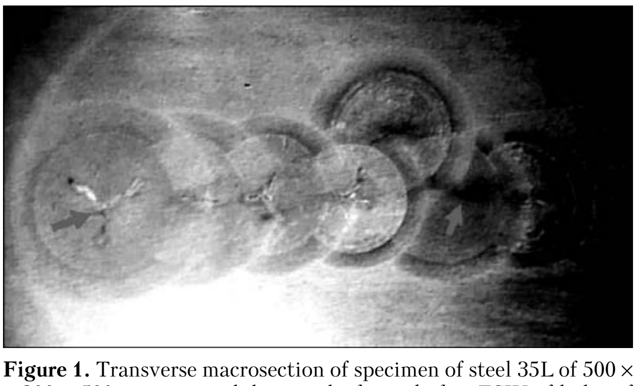

Figure 1. Transverse macrosection of specimen of steel 35L of 500 × × 300 × 500 mm size with hot cracks formed after ESW of holes of 50 mm diameter and 500 mm depth

The comparative analysis of efficiency of application of existing methods of repair of similar defects using fusion welding showed that the most promising technological process for repair of fractured bands directly at the site of their operation (at the furnace) is the multi-layer electroslag welding (MESW) [2, 3]. However its application is limited by the number of factors, one of which is a low resistance of weld layers to formation of crystalline cracks in the central part of the weld layers.

To study causes of initiation of these defects and to develop the technological methods of improving resistance of layers of multi-layer weld to formation of crystalline cracks, the number of experiments was carried out. The investigation was performed according to the procedure, including comprehensive study of experience of application of MESW, analysis of obtained results, development of new methods of welding and their practical realisation at making the MESW of specimens.

The sizes and material of specimens were selected similar to specimens-witnesses applied at manufacturing of bands of rotary furnaces (Figure 2). The welding machines of the type A-645 and A-1304 with power source TShS-3000-3, electrode wires of grades Sv-08GA and Sv-10G2 of 3 mm diameter, and also flux AN-8M were used. In the process of welding the main parameters of conditions were recorded using information-recording system ISU-150 [4]. The welded specimens were cut into templates, from which transverse and longitudinal macrosections were produced, the prints were taken according to Bauman.

Considering the peculiarities of electroslag welding (ESW) of large workpieces in thickness and sizes it turned out to be impossible to apply known methods of quantitative evaluation of resistance of a weld to formation of crystalline cracks [5–7]. Therefore, to obtain qualitative evaluation of metal resistance against hot cracks formation the so-called rigid samples were investigated [8]. According to these methods the specimens, similar by sizes and their mass to production workpieces (full-scale specimens), are welded. To increase rigidity, the fixing distance gaskets were placed into a welding gap (see Figure 2). As the criteria of evaluation of weld metal resistance against hot crack formation the specific heat input of welding was taken E_w, providing guaranteed fusion at minimal required penetration depth without hot crack formation.

With the purpose of providing the sufficient resistance margin of a weld metal to crystalline crack formation the preheating of full-scale specimens (rigid samples) was intentionally not performed before welding.

In MESW using vertical welds the rigidity of edges fastening was caused by mounting of transverse metallic bridges, forming the groove (see Figure 2). The rigidity of joint increases with layout of layers (increase of obstacle to free shrinkage of crystallizing metal). As far as decrease of rate of tensile deformation of weld metal by decrease in welding speed failed due to the loss of steadiness of electroslag process [5, 9] it was decided to change the conditions of formation of a multi-layer weld.

According to the selected methods the specimens (Figure 2) of the steels 30L and 34LESh were re-welded. The holes formed at mounting of plates of rolled metal were re-welded successively using dual electrode consumable nozzle at specific heat input E_w = 110–170 kJ/cm^2.

The study of transverse macrosections of welded joints of performed specimens showed that after re-welding of holes of rectangular shape the lines (areas) of fusion have an elliptical shape. The crystallites grow from the edges of parent metal in the direction of a centre, where meeting each other, they form a weld area with the least ductility (plane of weakness) [5, 10]. The plane of weakness is positioned along the large axis of ellipsis, thus parallel to the edges being welded. It is known [11] that development of a hot crack mainly occurs in the direction perpendicular to the action of the largest component of deformation (Figures 3, *a* and 4, *a*). Considering high rigidity of elements being welded and the fact that in the weld metal area of high temperature the transverse deformations are mainly developed, the most favourable conditions to hot crack formation are formed at this position of weakness area. It was also proved by carried out investigations.

Basing on the results of carried out experiments the suggestion was made about the possibility of decrease of negative influence of the area of the smallest ductility on technological strength using positioning of weakness plane parallel to the vector of the maximal tensile forces appeared at crystallisation of a weld metal (Figure 3, *b*). In order to check it, the groove of edges was formed using plates-spacers after mounting of which the rectangular holes appeared between the edges being welded. The largest side of the hole

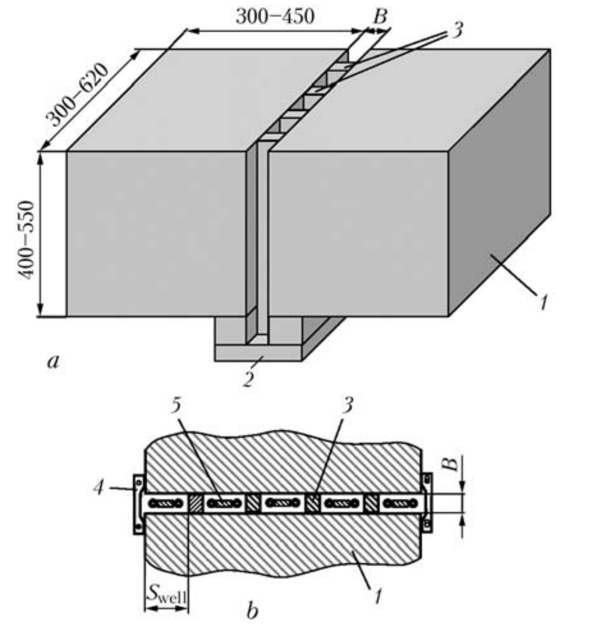

Figure 2. Scheme of assembly (*a*) and MESW (*b*) of pilot samples with longitudinal arrangement of consumable nozzles: *1* — parts being welded; *2* — input pocket; *3* — forming plates-spacers; *4* — water-cooled cover plate; *5* — consumable nozzle; *B* — width of welding gap; S_{well} — thickness of well metal

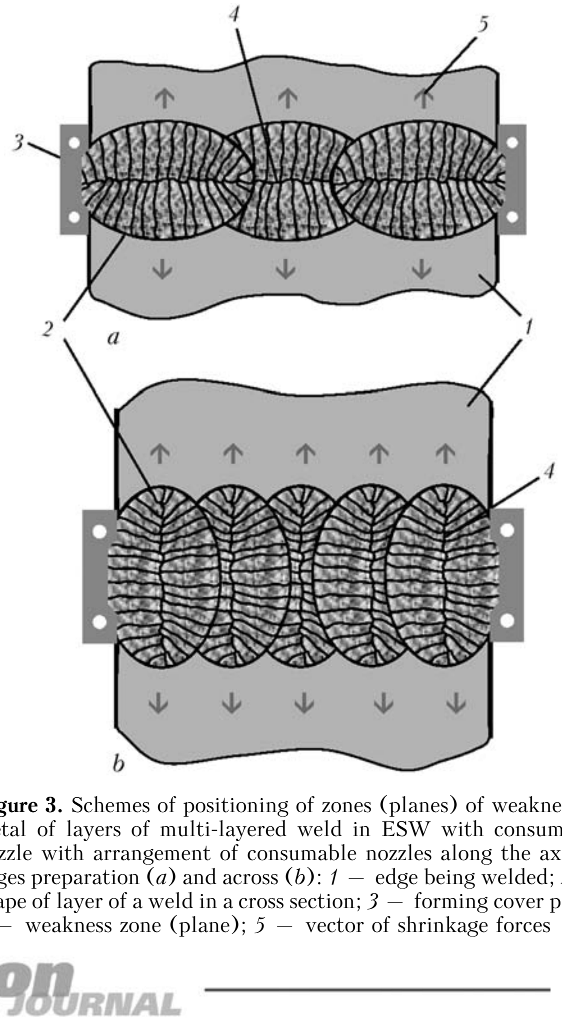

Figure 3. Schemes of positioning of zones (planes) of weakness in metal of layers of multi-layered weld in ESW with consumable nozzle with arrangement of consumable nozzles along the axis of edges preparation (*a*) and across (*b*): *1* — edge being welded; *2* — shape of layer of a weld in a cross section; *3* — forming cover plate; *4* — weakness zone (plane); *5* — vector of shrinkage forces

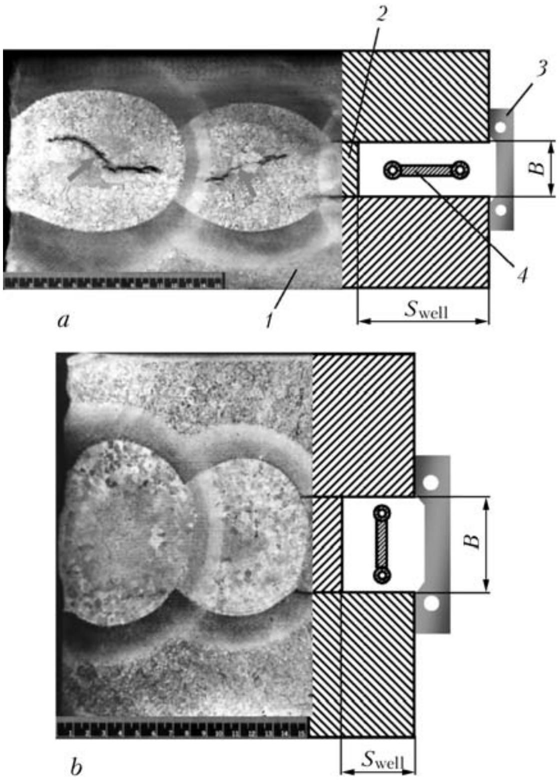

Figure 4. Transverse macrosections of multi-layer electroslag welds performed with longitudinal (*a*) and transverse (*b*) arrangement of consumable nozzles in a gap: *1* — billets being welded; *2* — forming plate-spacer; *3* — forming water-cooled device; *4* — consumable nozzle

(well) was positioned not parallel, but perpendicularly to the edges being welded (Figure 4).

ESW of the holes was performed using consumable dual electrode nozzles mounted across the welding gap according to the scheme in Figure 4, *b* at the specific power within the above-mentioned limits. The results of investigations of macrosections and Bauman's prints of transverse and longitudinal sections of welds performed according to the offered scheme showed that hot cracks in weld layers were not detected.

Thus, it was established that by changing the direction of weakness plane of single layers relative to the vector of tensile forces of multi-layer weld it is possible to achieve increase of its resistance against formation of crystalline cracks.

At the repair of through cracks in bands of rotary kiln furnaces the shape of groove of edges and pitch of layers being re-welded should be determined depending on the configuration and sizes of defects.

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