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APPLICATION OF NON-CONDUCTING CONSUMABLE BILLETS AT ELECTROSLAG SURFACING IN CURRENT-SUPPLYING MOULD

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The effect of increasing the distance from the processed surface to the current-conducting section of the current-supplying mould on base metal penetration, deposition rate and specific power consumption was studied at electroslag surfacing of end faces with application of non-conducting billets. Comparison of this effect on the quality of bimetal produced in electroslag surfacing with electrodes and non-conducting billets of the same cross-section was performed. It is found that application of optimal electric power to the slag pool through current-conducting section of current-supplying mould and of consumable billets allows achieving the set penetration of base metal, good formation of the deposited layer and process efficiency, commensurate with those obtained at surfacing with electrode of the same cross-section, only in the case of optimum distance from the melted edge of the consumable billet to the processed surface of the item. 13 Ref., 1 Table, 2 Figures.

Keywords: *electroslag surfacing of end faces, non-conducting large-section consumable billet, current-supplying mould, power sources, processed surface, base metal penetration, surfacing quality*

In addition to penetration, the most important parameters of electroslag surfacing (ESS) include the quality of deposited layer metal and its formation, and certainly, one of the main advantages of the electroslag process — increased surfacing efficiency, compared to other methods of producing bimetal by welding processes.

A large number of methods and engineering solutions of ESS performance have been proposed to produce sound bimetal products [1]. One of the simple, but at the same time effective methods is application of non-conducting filler, most often wire, alongside consumable electrodes in the electroslag process. This technique of addition of two melting welding consumables to the slag pool has become the most widely accepted in electroslag welding (ESW). Here, plates or electrode wires are used as electrodes [2–5], and the filler is additionally fed in the form of extruded or flux-cored wire and strips [6–8].

Application of additional filler results in improvement of the shape and dimensions of the metal pool, micro- and macrostructure of the deposited metal, as well as its mechanical properties; welding process efficiency is increased and power consumption is lowered. However, as noted in [5], further addition of cold filler to the slag pool cannot essentially change the amount of heat, coming to base metal from the metal pool. This is related to the fact that heat content of the metal pool is determined, mainly, by the temperature of drops falling into it from the molten electrode tip. Therefore, in ESS practice, unlike ESW, another direction of improvement of all the surfacing parameters has been developed. This is simultaneous application of both large-section consumable electrodes, and non-consumable electrodes at ESS [9–11]. In this case, however, although electric power applied to the consumable electrodes, can be decreased, nonetheless, the influence of overheated drops of electrode metal on metal pool temperature and on heating of the item processed surface, respectively, is preserved.

The work had the objective of achieving minimum and uniform penetration of base metal at good formation of the deposited metal by changing various process parameters (both electric, and geometrical) of ESS with ring-type non-consumable electrode, i.e. current-supplying mould (CSM), with application of non-conducting large-section billets instead of electrodes of the same size. It is of interest to compare the results obtained at ESS in CSM at alternating and direct currents, using large-section electrodes, with different electric connection circuits [12, 13], with the results of surfacing in CSM of the same size at melting of non-conducting consumable billets. Procedure of experiment performance is similar to that given in [13].

Figure 1 gives the electric connection circuit during performance of experiments on surfacing. Five experiments have been conducted at direct current (33M, 35M, 36M, 37M and 39M) and one experiment at al-

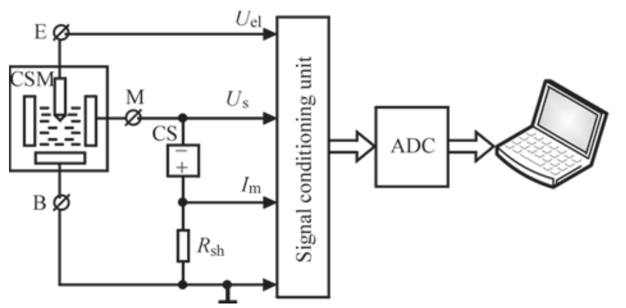

Figure 1. Diagram of electrical connections at performance of surfacing experiments (E, M, and B are the terminals of connection of the electrode, mould current-conducting section, and bottom plate with the item, respectively; CS is the direct current source; R_{sh} is the measuring current shunt; U_s, U_{el}, I_m are the signals proportional to current source voltage, supplied electrode voltage and mould (bottom plate) current, respectively; ADC is analog-digital converter)

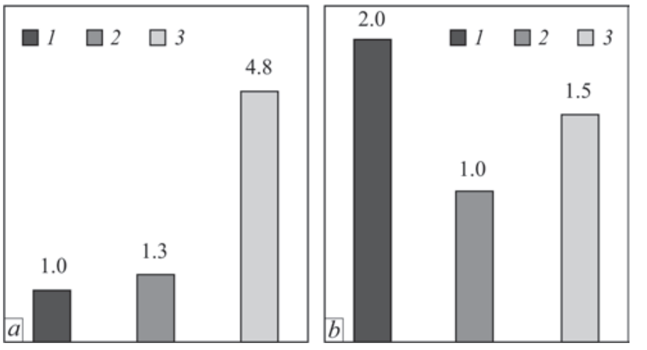

Figure 2. Histogram of comparison of minimum values of specific power consumption, kW·h/kg (*a*) and minimum values of average penetration depth, mm (*b*) obtained during performance of surfacing experiments in CSM (*1* — alternating current, for *a* — D_{el} = 130 mm; *b* — 90; *2* — direct current D_{el} = 90 mm; *3* — non-conducting billet, D_b = 115 mm)

ternating current (6M). In some experiments, position of the processed surface of the item relative to lower edge of current-conducting section of the mould was changed, namely this distance *h* was equal to 110, 70 and 44 mm. Experiments were performed with non-conducting consumable billets of two diameters of 90 and 115 mm. Longitudinal macrosections were cut out of all the surfaced samples for assessment of penetration depth and its uniformity over the fusion zone.

The Table gives the parameters of ESS modes and evaluation of the quality of bimetal samples, obtained during performance of these experiments.

Analysis of the results given in the Table, shows that indexes of surfacing quality for experiments, in which the distance from the processed surface to current-conducting section was large, namely 110 and 70 mm (6M, 33M, and 35M experiments), were better, than for 36M, 37M and 39M experiments, in which *h* = 44 mm. This is, supposedly, related to the fact that in the first case the slag pool volume and its heat capacity were greater, and it allowed ensuring fast heating of non-conducting billet edge to melting temperature at relatively low current value in the mould current-conducting section, and not overheating the item around the periphery near the forming section walls. Moreover, at greater depth of the slag pool there are wider possibilities for selection of consumable billet edge position in the slag. At small value *h* in practice it is difficult to «keep» the consumable billet edge at the required distance from the processed surface, and higher current in the mould current-conducting section increases the near-anode voltage drop on the item, and leads to deep penetration of its peripheral zone.

It follows from here that at technological schematic of surfacing with non-conducting billet, which offers much less possibilities for controlling the surfacing process, than the schematic with the consumable electrode, it is not rational to position the processed surface at a small distance from the mould current-conducting section.

Figure 2, *a* shows the histogram of minimum values of specific power consumption and minimum values of average penetration depth (Figure 2, *b*), obtained at performance of experiments on ESS in CSM at alternating [12] and direct [13] currents, as well as at application of non-conducting billet. Quality indexes of bimetal of 33M, 35M and 6M samples give grounds to assert that the process of surfacing by

ESS parameter values and assessment of the quality of bimetal samples produced in CSM

Experiment number	Billet diameter, mm	Current, kA	Voltage, V	Power, kW	V_b, mm/min	*G*, kg/h	*h*, m	*Q*, kW·h/kg	Surfacing quality		
									H_{av}, mm	Δ_{av}, mm	PSQ
33M	90	1.81	31.3	56.7	2.14	6.4	110	8.9	1.6	1.2	Satisfactory
35M	90	1.65	46.1	76.1	2.0	6.0	110	12.8	1.8	1.3	Same
36M	90	2.59	36.5	94.5	0.5	1.6	44	60.3	8.4	7.2	»
37M	90	2.57	35.3	90.7	0.42	1.2	44	73.1	8.1	7.2	»
39M	90	2.52	35.6	89.7	3.8	14.9	44	8.0	7.6	7.0	Good
6M*	115	2.2	36	79.2	6	16.5	70	4.8	1.5	1.0	Same

Note. * — surfacing was performed at alternating current; V_b — the average speed of billet movement; *G* — deposition rate; *h* — distance from processed surface to current-conducting section; *Q* — specific power consumption; H_{av} — average penetration depth; Δ_{av} — average non-uniformity of penetration; PSQ — processed surface quality (expert evaluation).

the schematic with non-conducting billet can compete with ESS by consumable electrode both at alternating and at direct currents (Figure 2, *b*). In any case, however, it is necessary to take into account the position of consumable billet edge in the slag pool relative to the processed surface, as this parameter has a great influence on H_{av} and Δ_{av} values. This fact is confirmed by the results of experimental ESS (36M, 37M and 39M experiments) (see Table). All the three samples were obtained as a result of melting of 90 mm billets at practically the same currents and voltages and the same distance from the processed surface to CSM current-conducting section (44 mm), as in this case the specific power consumption values differ considerably. This is attributable to uncontrolled change of the position of consumable billet edge in the slag relative to the processed surface. Frequent removal of the billet from the slag pool (for assessment of the position of the billet edge in slag) had a certain influence on the results, promoting lowering of the values of average speed of billet movement.

It is also obvious that ESS with application of non-conducting consumable billets cannot compete with ESS with consumable electrode as to deposition rate and specific power consumption. Electrode melting rate in CSM is higher a priori, than that of non-conducting billet, and ESS efficiency is higher, respectively. In its turn, heating of non-conducting billet to melting temperature through heating of the slag pool at passage of just mould current through it (unlike ESS with consumable electrode), leads to reduction of the concentration of applied power near the billet, that increases the specific power consumption in ESS with non-conducting billet (Figure 2, *a*).

Data obtained from 6M experiment show that at sufficient power applied to CSM, and optimum position of the edge of non-conducting consumable billet relative to the processed surface, good values of base metal penetration at high power efficiency of the surfacing process can be achieved.

Apparently, it rational to apply surfacing with non-conducting consumable billet in those cases, when, despite an increased power consumption, achieving minimum penetration is a mandatory condition for joining metals with markedly differing properties and definitely forming brittle structures in the fusion zone even at their slight mixing. Such a technology allows more reliably achieving minimum penetration, than in surfacing with large-section electrode by the schematic with the same potentials on the electrode and CSM current-conducting section.

In conclusion it should be noted that at ESS with non-conducting consumable billets sound bimetal joints can be obtained at relatively small distances from CSM current-conducting section to the processed surface, determined by surfacing modes and chemical composition of the applied flux. Here, the position of its edge in the slag pool relative to the processed surface should be taken into account, as this parameter has a great influence on base metal penetration values.

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