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ELECTROSLAG SURFACING OF BILLET END FACES WITH APPLICATION OF CONSUMABLE AND NONCONSUMABLE ELECTRODES

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Producing minimum and uniform penetration of base metal at electroslag surfacing of end faces by consumable electrode of a large cross-section is a complex task. The most promising is the application of nonconsumable electrode – current-supplying mould for these purposes. Influence of different electric circuits of connection of electrodes of different diameter from one or two AC power sources on base metal penetration was studied. It is found that from the viewpoint of optimizing the surfacing technology (achievement of not only quality indices, but also increased process efficiency), it is promising to apply the surfacing circuit with one power source and the same potentials on the bottom plate and current-conducting section of the current-supplying mould. Circuit of electroslag surfacing with two sources allows producing similar results, but it is more complicated to implement (presence of two sources) and less cost-effective, respectively. Obtained results can make up the data bank for designing a system of automatic regulation of base metal penetration at electroslag surfacing of end faces. 11 Ref., 1 Table, 3 Figures.

Keywords: *electroslag surfacing of end faces, large cross-section consumable electrode, current-supplying mould, AC power sources, base metal penetration*

Proposed by the staff of Donetsk National Technical University technology of electroslag surfacing of end faces, which they called bulk ESS, is quite widely accepted for reconditioning various products, mainly excavator bucket teeth. Various surfacing techniques are used, and electrodes can be both composite, and standard ones [1, 2]. As a result, the size of the transition zone cannot be greater than 300 μm [3, 4]. Obtaining small values of the transition zone often requires stringent conditions for conducting the electroslag process. In particular, in the case of, for instance, application of electroslag heating at surfacing, the metal pool depth and base and deposited metal mixing increase markedly at insufficient time of its impact [4]. Thus, the quality of single-electrode ESS in a standard water-cooled mould depends on a multitude of factors influencing the final result of surfacing.

In [5] it was shown that the required bimetal characteristics can be obtained at application of nonconsumable electrode – current-supplying mould (CSM) and one power source, but it is rather difficult to ensure the stability of its quality from one surfacing operation to another one.

As regards electroslag remelting (ESR) in CSM, in order to obtain a relatively flat metal pool the authors of [6, 7] suggest applying the so-called two-loop (two power sources) circuit of conducting the electroslag process. And even though the influence of various process parameters on reaching the posed goal is considered in sufficient detail in these works, still these data belong to the technology of producing ESR ingots. It remains unclear what position of the edge of surface-melted electrode in the slag pool should be regarded as the optimal one. In our opinion, solving this problem is the most important from the viewpoint of automation of the process of regulation of base metal penetration at ESS. Now, practical confirmation of the possibilities for application of the two-loop circuit, when producing steel-copper billets of d.c. arc furnace anodes [8] is not quite convincing, as the depth of metal pool in melting highly heat-conducting metal (copper) is relatively small [9].

Repeatability of quality characteristics of bimetal billets can be ensured by optimizing both the electrotechnical (kind of applied current, circuits of connection of consumable electrode of different diameter, number of power sources) and geometrical parameters (position of processed surface relative to CSM current-conducting section, position of consumable electrode edge relative to the processed surface).

*Engineer A.I. Evdokimov took part in surfacing experiments.

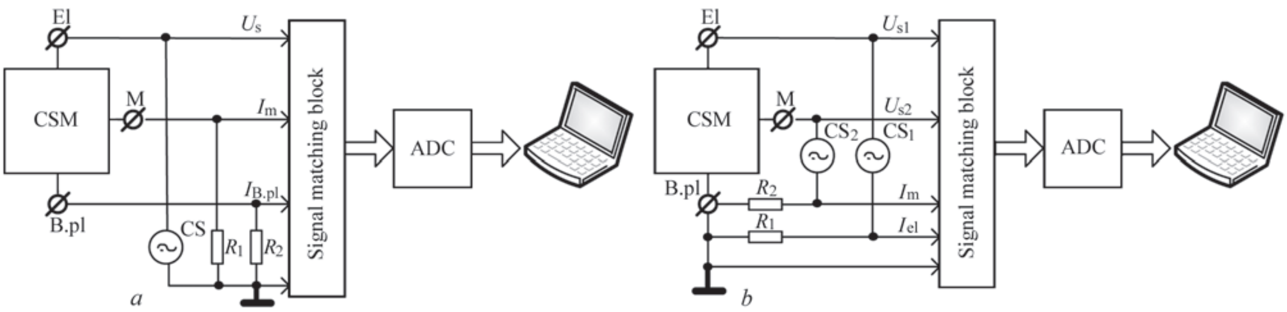

Figure 1. Block-diagram of electrical connections at performance of experiments for single-loop (*a*) and two-loop (*b*) ESS (E, M, and B.pl are the terminals for connection of the electrode, current-conducting section of the mould and bottom plate to the billet, respectively; CS is the AC source; R_1, R_2 are the instrument current shuts; U_s, I_m, $I_{b.pl}$, I_{el} are the signals proportional to power source voltage, mould current, bottom plate current and electrode current, respectively; ADC is the analog-digital converter)

This work is a continuation of earlier started research on ESS of end faces with large-section electrode in CSM [5]. The paper provides analysis and comparison of various engineering solutions from the viewpoint of cost-effectiveness of the surfacing process, simplicity of its implementation and stability of surfacing quality results. Various electric circuits of connection of electrodes of different diameter to one or two a.c. power sources are taken as variable parameters. Alternating current was selected for surfacing as the most widely accepted one in electroslag technologies [10, 11]. It is also intended to use the data obtained as a result of test surfacing performance at development of a system of automatic regulation of base metal penetration.

Surfacing experiments, similar to [5], were performed with ANF-29 flux in CSM of 180 mm diameter with 40–130 mm electrodes from steel 40. Steel St.3 billets 20 mm thick were fixed on a water-cooled bottom plate. TShP-10 and TShS-3000-1 were used as power sources.

Figure 1 shows the block-diagram of electrical connections during performance of experiments for single-loop (*a*) and two-loop (*b*) ESS. Measurement and recording of currents and voltages was conducted using a versatile ADC module E14-440 (USB2 bus), LENOVO notebook IdealPad Y650 model with 64-bit operating system and PowerGraph software (SW). Signals in the form of voltages, proportional to currents in the source circuits, were read using instrument current shunts R_1 and R_2. Voltages of current sources and signals of currents in the source circuits were entered through signal matching unit, which had the role of overload protection and high-frequency interference filter, into ADC with discretization frequency of 1.0 kHz, and then into the computer for processing. Power Graph SW was used to calculate effective values of entered signals of alternating current and voltage, and then these were stored in the computer memory. Figure 2 shows a fragment of recording the surfacing process parameters (22M experiment).

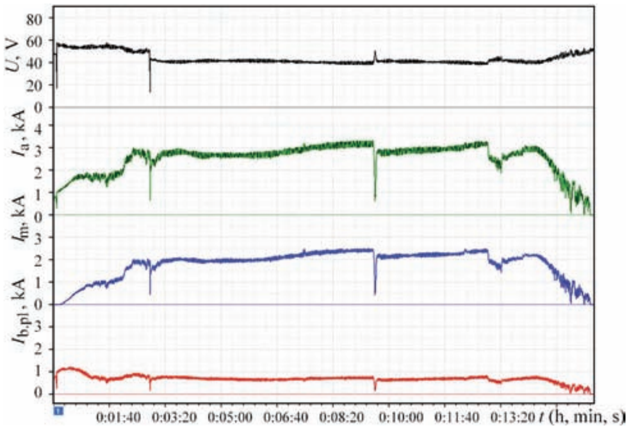

Figure 2. Fragment of recording the surfacing process parameters (22M experiment)

The Table gives the results of experiments on investigation of the influence of electric parameters of the process of ESS in CSM (at application of electrodes of different diameter and their connection circuits) on base metal penetration. Experimental results were used to analyze the macrosections of the produced bimetal, and calculate the average depth of billet penetration and average nonuniformity of its penetration. As an example, Figure 3 shows a macrosection of a bimetal sample (25M experiment). Dotted line denotes the zone of metal mixing.

Average penetration depth H_{av} was defined as $H_{av} = S_{up}/D_b$, were S_{up} is the macrosection surface area between the item upper level and item penetration line; D_b is the blank diameter. Average nonuniformity of billet penetration Δ_{pen} was defined as $\Delta_{pen} = S_{\Delta}/D_b$, where

Figure 3. Macrosection of bimetal sample (25M experiment). Dotted line denotes metal mixing zone

ESS mode parameters and assessment of the quality of bimetal samples made in CSM

Experiment number	Electode diameter, mm	Connection circuit	Current, kA		Voltage, V		N_{tot}, kV·A	N_{CSM}/N_{el}	v_{el}, mm/min	G, kg/h	h, mm	Q, kW·h/kg	Surfacing quality		
			CSM	Electode	CSM	Electode							H_{av}	Δ_{av}	QPS
21M	130	OC	2.5	3	0	44	132	45/55	18	135	85	1	8	3	Good
22M	90	Same	2.1	2.8	0	41	115	43/57	18	50	85	2.3	7	3	Excellent
23M	40	»	1.5	2.4	0	50	120	38/62	110	34	85	3.5	3	1	Same
25M	90	TC	3.2	2.4	37	68	293	43/57	49	42	85	6.9	2	1	Good
26M	90	Same	1.2	2	42	11	72	31/69	51	10	85	7.2	4	2	Same
28M	40	»	2.6	1.6	33	40	150	43/57	76	28	85	5.4	2	1	Excellent
29M	40	»	2.3	1.2	32	42	124	41/59	89	24	61	5.2	15	8	Good

Note. OC, TC are the one-loop and two-loop circuits of CSM connection, respectively; N_{tot} is the total power consumed by CSM; N_{CSM}/N_{el} is the ratio of powers in the mould and electrode; v_{el} is the speed of electrode movement; G is the deposition efficiency; h is the distance from the processed surface to the upper edge of forming section; Q is the specific power consumption; H_{av} is the average penetration depth, mm; Δ_{av} is the average nonuniformity of penetration, mm; QPS is the quality of processed surface formation (expert assessment).

S_Δ is the macrosection surface area, limited by line H_{mid} and item penetration line. Quality of processed surface formation (QPS) was assessed by three experts.

Obtained data confirm that ESS with application of one-loop power circuit with the same potentials on the bottom plate and CSM current-conducting section (21M, 22M and 23M experiments) provides a higher efficiency that does the two-loop circuit of ESS with a common point of power sources connection on the bottom plate (25M, 26M, 28M and 29M experiments). This is, obviously, related to the fact that at surfacing the fraction of current flowing through the electrode is much higher in the first case than in the second one. In this connection, it is of interest to study ESS by the two-loop circuit with a common point of power sources connection on the electrode, having, supposedly, a higher efficiency, than that with a common point of connection on the bottom plate. It should be noted that the two-loop circuit of ESS with a common point of both the power sources connection on the bottom plate is the traditional circuit for application of two power sources at ESR in CSM [6–8].

For all the experiments, including also ESS by two-loop circuits, practically the same power ratio N_{CSM}/N_{el} (31–45)/(55–69) was ensured. In these experiments, similar to [6–8], ESS by a two-loop circuit with power ratio in favour of the mould, was not used, as in this case, in our opinion, the fraction of power on the electrode during surfacing is reduced, and ESS by the two-loop circuit will lead to even greater lowering of deposition efficiency, because of lowering of electrode melting rate.

Experiments showed that ESS by one-loop circuit with application of 40 mm electrode (23M experiment) can compete, in terms of such parameters as H_{av} and Δ_{pen}, with ESS by the two-loop circuit (28M experiment). Reduction of the distance from the processed surface to the upper edge of the forming section from 85 to 61 mm (28M and 29M experiments) led to a significant increase of average penetration depth (from 2 to 15 mm) and average nonuniformity of penetration (from 1 to 8 mm). This is, probably, related to increase of the degree of impact of hot molten metal on the billets. Changing electrode diameter from 130 to 40 mm led to reduction of both H_{av} and Δ_{pen}.

Conclusions

1. The possibility of performance of end face ESS with various electric circuits of connection of electrodes of different diameter from one or two AC power sources was established, and the influence of electric and process parameters on base metal penetration was studied.

2. It is shown that the surfacing circuit with one power source and the same potentials on the bottom plate and current-conducting section of CSM (nonconsumable electrode) can be considered promising, from the viewpoint of producing an optimum surfacing technology (achievement of not only quality indices, but also increased process efficiency).

3. ESS circuit with two sources allows producing results similar to those at ESS with one power source, but it is more complex to implement (presence of two sources), is characterized by lower efficiency and accordingly, is less cost-effective.

4. It seem promising to study ESS by a two-loop power circuit with a common point of connection of both the sources on the electrode, having, supposedly, a higher efficiency that the circuit with a common connection point on the bottom plate.

5. Obtained results can make up a data bank for development of a system of automatic regulation of base metal penetration at end face ESS.

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