DOI: http://dx.doi.org/10.15407/tpwj2019.04.07

FORMATION OF METAL POOL IN CURRENT-SUPPLYING MOULD AT ELECTROSLAG PROCESS

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Results of experiments were presented on study of the effect of different technological parameters on the formation of a metal pool in electroslag surfacing with a discrete filler either in the form of electrode or no-current large-section billet in current-supplying mould. It was found that the metal pool shape can be affected by changing the electric mode of the process, electrical scheme of connection of the current-supplying mould using direct and alternating current. The ways of producing a favorable metal pool shape at increased efficiency of the electroslag process are shown. 8 Ref., 2 Tables, 2 Figures.

Keywords: *circumferential and edge electroslag surfacing, current-supplying mould, metal pool*

Volume and shape of the metal pool are among those factors, determining the metal quality both of the ingots, as well as deposited layers, produced during electroslag melting of consumable electrodes in a conventional water-cooled mould [1–3]. In electroslag surfacing (ESS) the depth and uniformity of base metal penetration depend on the metal pool shape. At its more shallow shape, the probability of producing quality mixing of metals is increased in a number of cases.

The same factors are also important for the metal, solidifying in a current-supplying mould (CSM). In spite of design differences of CSM from a conventional mould (4–7) and, respectively, another conditions of distribution of electric current in a slag pool (independently of type of metal being remelted), the solidification of metal in a CSM forming section is governed by the same laws) [8].

The aim of the present work is to evaluate the effect of technique and technology of electroslag surfacing in CSM on formation of pool of metal being remelted. During investigations the following techniques and technologies were considered: surfacing with electrodes or no-current large-section billets or a discrete filler, making of edge or circumferential surfacing, application of different schemes of CSM connection, application of one or two DC or AC power sources.

During the edge surfacing, the CSM of 180 mm diameter and steel electrodes or no-current billets of steel X70 of 40–130 mm diameter, as well as chips of low-alloy steel after milling were used. The circumferential ESS of 100 and 150 mm diameter parts was performed by 2–3 mm diameter shots of non-alloyed and chromium cast iron in CSM of 200 and 250 mm diameter, respectively. Power sources were transformers TShP-10 and TShS-3000-1, as well as rectifiers VDM-5000 and VDU-1202. Electrical schemes of CSM connection in electroslag process using a discrete filler and electrodes (billets) are given in Table 1.

Electrical mode of surfacing was selected with account for a stable electroslag process.

The electroslag process was started at a «solid» start (by means of a water-cooled electrode with a graphite headpiece) or at a «liquid» start (flux was melted in a graphite crucible). The working fluxes were AN-75, ANF-29, ANF- 32.

The shape of a metal pool bottom was fixed by introducing the portions of solid alloy granules or chromium cast iron shots of a fine fraction into a molten metal, supplied to the slag pool surface during surfacing of steel layers.

In some cases the bottom shape was set by a special etching of deposited metal to determine the direction of crystal growth and location of liquid phase surface, corresponding to it.

The macrosections of specimens, produced at the edge and circumferential electroslag deposits with a discrete filler and large-section electrode, are shown in Figure 1.

As is seen from Figure 1, during the edge ESS the metal pool shape, produced due to metal of the molten filler, has a specific shape of a «sombrero» type with a peak in center of a layer deposited and depressions along its edges. This shape is defined by a CSM design and, respectively, by a special distribution of electric current in slag and metal pools (Figure 2). Reduction in difference of heights of peak and depression parts of the layer can be attained by applying special technological procedures.

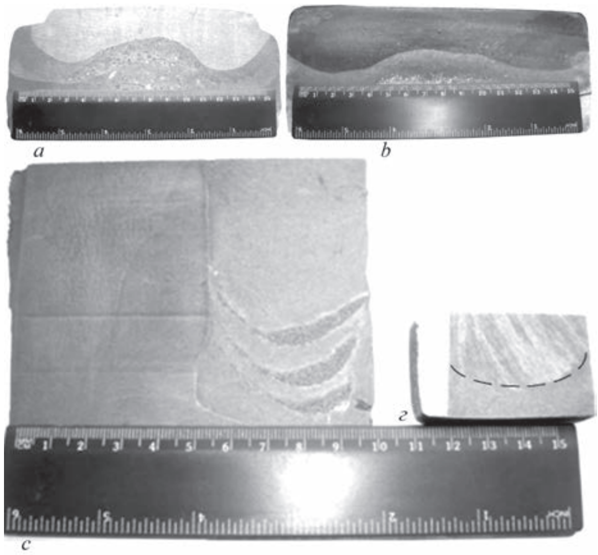


Figure 1. Longitudinal macrosections from specimens, deposited by different technologies: edge surfacing with low-alloy steel chips by electric scheme 1 (*a*) and with large-section electrode by electric scheme III, electrode $Ø_{el}$ = 90 mm (*b*); circumferential surfacing by nonalloyed (*c*) and chromium cast iron (*d*) shots by electric scheme Ia

In case of application of consumable electrodes (billets) during edge ESS the pool shape can also be corrected, which will be discussed below.

During the circumferential ESS with a discrete filler the metal pool shape is similar to the shape, produced in surfacing with a large-section electrode (for example, tubular electrode) and can be changed both due to the electric mode of surfacing and also by the mass rate of filler feeding into the slag pool.

The effect of a kind of current used, electric scheme of CSM connection and diameter of consumable elec-

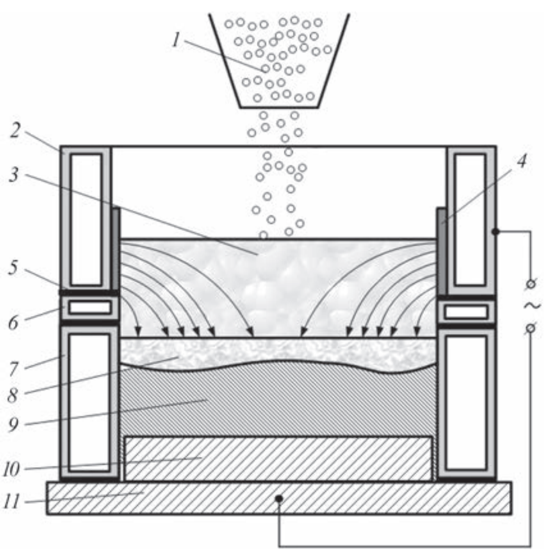


Figure 2. Scheme of distribution of electric current in slag and metal pools in edge ESS in CSM: *1* — discrete filler; *2*, *6*, *7* — current-carrying, intermediate and forming sections of mould, respectively; *3* — slag pool; *4* — protective lining; *5* — insulating gasket; *8* — metal pool; *9* — deposited metal; *10* — workpiece; *11* — bottom plate

Table 1. Electric schemes of CSM connections during electroslag process with use of a discrete filler and large-section electrodes (billets)

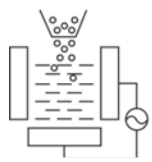
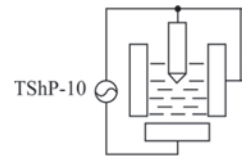
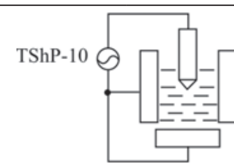
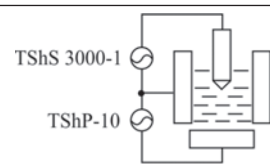
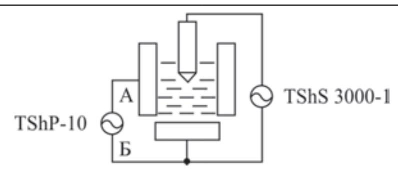
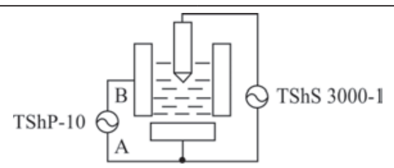
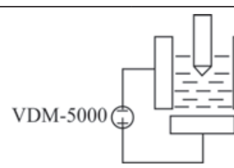
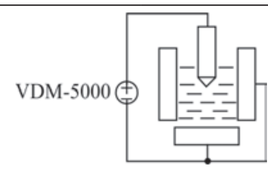
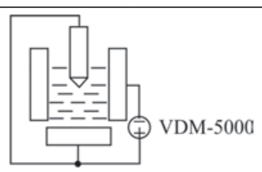
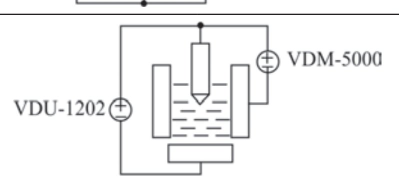
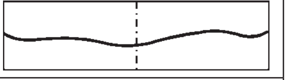
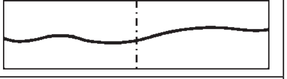
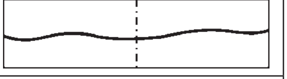
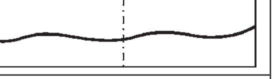
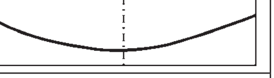
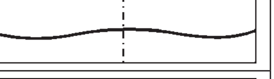
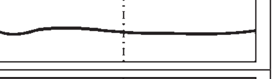
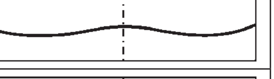
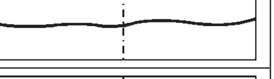
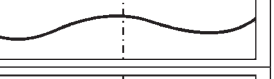
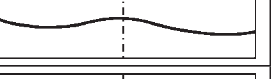
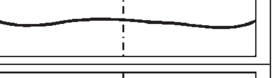
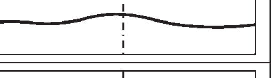
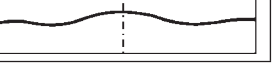
Designation of scheme	Electric scheme of CSM connection	
I, Ia		
II		
III		
IV		
V		
VI		
VII		
VIII		
IX		
X		

Table 2. Shape of metal pool bottom under different conditions of edge ESS process with large-section electrode (billet)

Number of experiment	Kind of current	Type of metal remelted (electrode/billet)	Diameter of electrode/billet, mm	Designation of electric scheme	ESS parameters		Shape of metal pool bottom
					Current at CSM, kA	Efficiency, kg/h	
8M	Alternating	Electrode	90	II	1.5–2.5	9	
9M	Same	Same	130	II	1.5–3.5	17	
14M	»	»	40	III	1.4–2.2	39	
16M	»	»	90	III	1.6–3.1	39	
18M	»	»	90	Conventional ESR	2.1–2.8	51	
21M	»	»	130	III	3.0–3.3	136	
22M	»	»	90	III	2.4–3.0	50	
23M	»	»	40	III	1.9–2.6	34	
24M	»	»	90	IV	1.9–2.0	7	
25M	»	»	90	V	1.9–3.7	42	
26M	»	»	90	VI	1.0–2.2	27	
29M	»	»	40	VII	1.8–2.6	24	
30M	»	»	130	VI	2.0–3.3	70	
39M	Direct	Billet	90	VII	2.6–2.8	20	
44M	Same	Electrode	90	VIII	1.0–1.6	39	
46M	»	Same	90	IX	1.6–2.5	21	
47M	»	»	90	X	1.0–1.1	69	

trode (billet) on metal pool shape at edge ESS is given in Table 2.

For comparison, the pool shape produced by remelting (ESR) of electrode in the same forming section of CSM of 180 mm diameter, at disconnection of its current-carrying section from the power source, i.e. transformation of CSM into conventional mould (experiment number is 18M) is presented.

From the results of experiments, presented in Table 2, the following conclusions can be made:

• it is possible to produce the most shallow shape of metal pool by use of one DC power source;

• use of two DC power sources complicates the surfacing technology, somewhat deteriorates the pool shape, but allows increasing the process efficiency by 1.5–2.0 times at a relatively low current, supplied to the mould current-carrying section;

• melting of nocurrent billet in slag pool, heated by passing of electric current in it, allows producing a shallow shape of metal pool, but this technology is characterized by a low efficiency of the electroslag process;

• at alternating current, which is the most frequently applied in electroslag processes, it is possible to provide the pool shape, comparable with a shape, attained in DC electroslag process;

• at the CSM connection scheme to one AC power source it is possible to produce the relatively shallow pool shape at different diameters of consumable electrodes;

• at the scheme with one AC power source for producing an optimum ratio of the pool shape characteristics and process efficiency it is preferable to apply the variant with different potential at electrode and workpiece.

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Received 06.03.2019