DOI: https://doi.org/10.37434/tpwj2022.07.06

CURRENT-SUPPLYING MOULD IN ELECTROSLAG TECHNOLOGIES

Yu.M. Kuskov, V.M. Proskudin, V.A. Zhdanov, L.L. Okopnyk

E.O. Paton Electric Welding Institute of the NASU
11 Kazymyr Malevych Str., 03150, Kyiv, Ukraine

ABSTRACT

The technology of electroslag surfacing and remelting, using a current-supplying mould, as well as the features of a mould design are considered. Experience of upgrading the basic three-sectional design into a two-sectional one is described. Ways of development of electroslag surfacing technology with application of current-supplying moulds of different dimensions and cross-sections are shown.

KEYWORDS: electroslag surfacing and remelting, current-supplying mould

INTRODUCTION

It has been about 70 years since a new technological process — electroslag process was officially recognized. During these years, various methods of electroslag welding and surfacing have been developed, which have found a wide application in industry and have already become “conventional”.

As for the method of electroslag surfacing (ESS) in the current-supplying mould (CSM), such recognition and distribution did not occur. It was caused by the difficulties in its practical realization, mainly due to a low life of the applied unit — current-supplying mould.

The aim of the work is to show some difficulties in creating a new type of moulds, their design and technological features, as well as prospects for the development of this technology, taking into account the success achieved in its industrial application.

For the first time, a nonconsumable section electrode — a mould — without any additional electrodes, was presented in the early 1960s by G.V. Ksyondzyk, staff colleague of the PWI of the NAS of Ukraine, in co-authorship with I.I. Frumin and V.S. Shyrin [1, 2] and patented in many countries [3-5]. The division of functions of melting a deposited material and formation of the deposited layer in it were achieved by the use of various sections of the mould electrically isolated between each other in the technological process.

The scheme of the mould is presented in Figure 1. It consists of separate horizontal water cooled sections *2*, *6* and *7*, separated between each other by electric insulating gaskets *5*. To the upper section *2*, which conducts an electric current, the voltage from the power source is supplied; the lower section *7* forms a deposited metal; the intermediate section *6* is used to divide the upper and lower sections. It can also be an element of automatic tracking of the metal pool level *8*.

To protect the upper section against the electric erosion, it has a protective heat-resistant conductive lining 4, which is usually made of graphite. Electric erosion is a phenomenon inherent in both CSM, as well as in ordinary moulds used in the technologies of electroslag remelting (ESR) [6]. At the same time, the resistance of new ESR moulds withstands in average 250 melts, but if an average duration of each melt is 2.5 h, it ranges from 150 to 350 melts.

It should be noted that if in the conventional moulds, the current passing on the mould wall, depending on melting parameter ranges from 10–20 to 90 % of the total current [7], then during ESS in CSM, through the current-supplying section, the entire working current passes. Therefore, in this case, electric erosion pro-

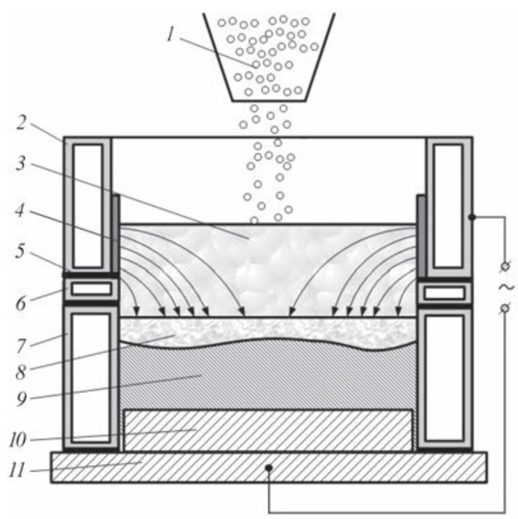

Figure 1. Scheme of ESS with a discrete filler in CSM: *1* — discrete filler; *2*, *6*, *7* — current-supplying, intermediate and forming sections of the mould, respectively; *3* — slag pool; *4* — protective lining; *5* — insulating gasket; *8* — metal pool; *9* — deposited metal; *10* — product; *11* — bottom plate. Arrows show distribution of current in the slag pool

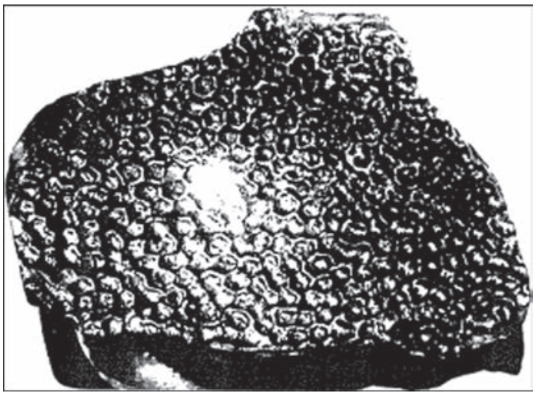

Figure 2. Surface of the slag crust that was in contact with the eroded surface of the wall of the current-supplying section (in the absence of lining): working currents are up to 1 kA, operation time is 1 h (×7)

cesses should run more intensively. Figure 2 shows the surface of a slag crust that was in contact with an eroded wall surface of the current-supplying section.

One more feature of CSM is that in its current-supplying section, a longitudinal incision is made, which is usually filled with a heat-resistant electric insulating material, as a result of which this section represents a single-turn inductor. The magnetic power lines of this inductor, interacting with the magnetic power lines of welding current, generate a rotary effect in the slag pool (which is also transmitted by friction forces on a metal pool). This additional property of CSM allows getting special advantages in ESS: improving equalizing of temperatures over the volume of the slag pool, providing a uniform distribution of a surfacing filler over the surface of the slag pool, reduction in electric erosion phenomena by decreasing a number of local zones for conducting current to the slag pool.

To start operation of the mould, the slag pool *3* should be created in it. This can be done in two ways:

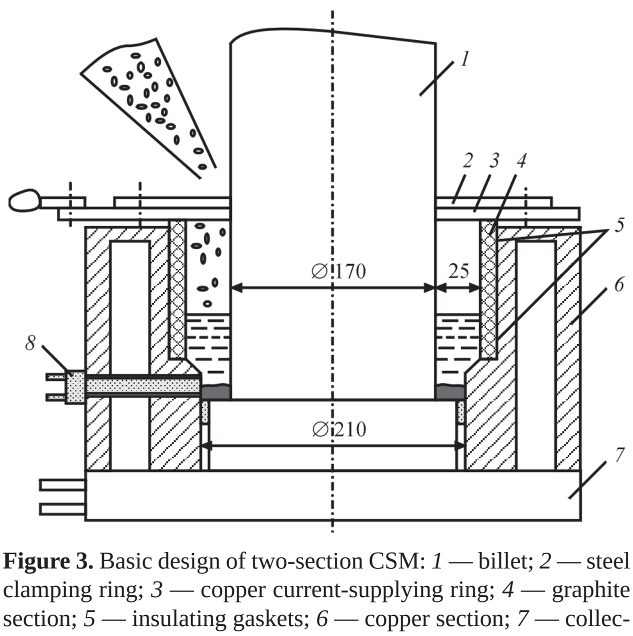

Figure 3. Basic design of two-section CSM: *1* — billet; *2* — steel clamping ring; *3* — copper current-supplying ring; *4* — graphite section; *5* — insulating gaskets; *6* — copper section; *7* — collector; *8* — inductive sensor of metal level

by its formation directly in the mould using an additional non-nonconsumable electrode (solid start), or by pouring a liquid slag into the mould, preliminary molten in a separate capacity (liquid start). In both cases, the volume of the slag should be so that it could cover all three sections. As a conductive medium, it begins to conduct current from the upper (current-supplying) section through the metal pool *8* to the deposited metal *9*, the product *10* and the bottom plate *11*. Regardless of the electroslag process parameters, a discrete filler *1* is supplied into the slag pool, which during melting in a slag, crystallizes in the lower forming section. In the case of using consumable electrodes in ESS, various electrical circuits of their melting in the slag pool can be used [8].

As is seen from Figure 1 and description of the operation of the mentioned unit, these circuits in design and technological terms are quite simple.

But it should be admitted that in the author's certificate, a rational idea was first and foremost stated on this design. Therefore, with all its simplicity, it took more than ten years to obtain the first encouraging results of operation of the proposed mould. Mostly, this was associated with an increase in its life. Nevertheless, there were problems with the choice of an optimal composition of the flux, open circuit voltage of the power source and the circuit of electrical connection. As an example of optimization of CSM design, in Figures 3 and 4, the variants of creating a two-section CSM for surfacing cylindrical parts are shown.

A distinctive feature of the basic model of such a mould (Figure 3) is the absence of an intermediate section, which is subjected to the most complex thermal conditions, and the use of a graphite bushing as a current-supplying element, isolated from the forming section over the vertical surface and a lower end.

Under such a scheme after pouring the slag into the mould, as a result of a rapid destruction of the insulation, not slag, but arc process begins. The cases of increased erosion destruction of the copper wall of a water-cooled mould and a copper current-supplying ring are observed.

In connection with the obtained result, some design changes were introduced — a graphite bushing was made with a clamp to provide better electrical contact in the current conducting zone and with a boundary vertical section along its length (Figure 4).

The constant rotation of the slag pool could not be achieved due to the appearance of reduction-oxidation reactions in the section area of electric-supplying products, occurring at the border graphite-slag. On the horizontal surface of a copper section in the zone of its close vicinity with the end of a graphite bushing, traces of erosion were noted.

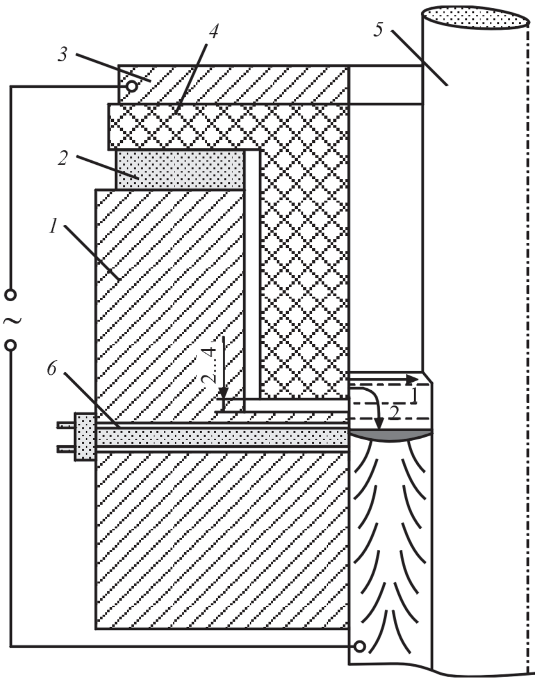

Figure 4. Two-section design of CSM with a clamp on the graphite section: *1* — copper section; *2* — insulating gasket; *3* — copper current-supplying ring; *4* — graphite section; *5* — workpiece; *6* — inductive sensor of metal level; I*1*, I*2* — respectively, horizontal and vertical components of current

The authors of the patent called the unit they developed a “current-supplying mould”, although this name does not fully reflect the physical content of the processes that occur.

The fact is that the voltage is supplied to the mould from the power source. The mould itself (or rather its upper section under voltage), being an element of the electrical circuit power source – upper section – slag pool – metal pool – workpiece – bottom plate, conducts a current passing on it. Therefore, it would be more correct to call this unit a “mould under voltage” or a “current–conducting mould”.

Due to the fact that the original name has already been rooted in the technical literature, the term with the abbreviation CSM should be used, proposed by the authors.

The idea of using ingots during melting or units during surfacing, that simultaneously affect proceeding of the electroslag process and provide the formation of the molten metal is so attractive, that it became used in different variants both in the countries of near and far abroad [9–11].

The “Inteco” Company (Austria) received several patents for melting ingots using CSM [12, 13].

Figure 5 shows one of such methods based on the patent [14]. Its distinctive feature is that during remelting, the voltage is supplied from one power source both to the consumable electrode and also to one of the sections (intermediate) of the mould, which

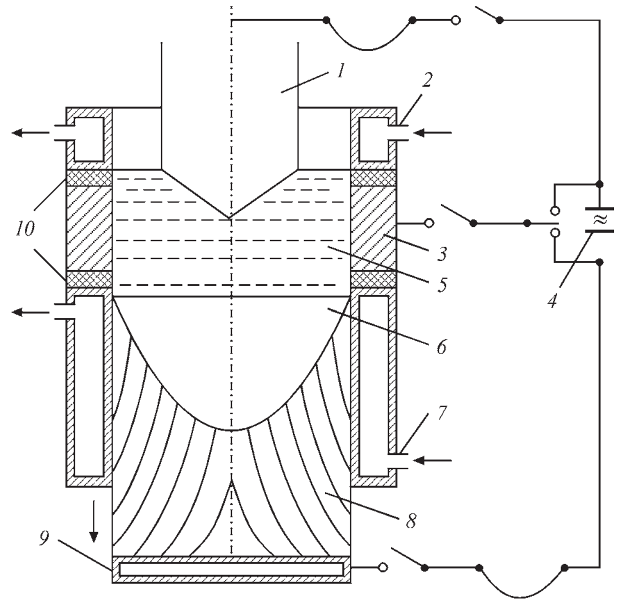

Figure 5. Scheme of section mould based on the patent DE 196 14 182 C1 of Germany: *1* — consumable electrode; *2* — upper section of the mould; *3* — intermediate section of the mould; *4* — power source; *5* — slag pool; *6* — metal pool; *7* — lower section of the mould; *8* — deposited metal; *9* — bottom plate; *10* — electric insulating gaskets

are made of graphite or refractory metals W, Mo, Nb, etc. and isolated from other sections.

This technology received an industrial application during a rapid melting of ingots made from high-speed steels using the method of ESRR (Electro Slag Rapid Remelting) [15].

The further development of ESS technology in CSM was the use of not only electrodes of a large cross-section and a discrete filler in surfacing, but also a filler in the form of a liquid material [16]. At the same time, with an increase in sizes (diameter) of the mould, it is proposed to use a current-supplying section with a large number of vertical sections [17, 18] to provide a uniform penetration of a workpiece surface.

Recently, to expand the capabilities of ESS in CSM, technologies for producing bimetal of a square cross-section were developed [19]. In this case, in the moulds of this type, all the technical features inherent in CSM of a round cross-section are preserved.

Thus, on the basis of the obtained results of a successful industrial testing of ESS technology in CSM using the moulds of two shapes of a working cross-section (round and square), it can be assumed that it became possible to create an operable technology of surfacing and the units for its realization.

REFERENCES

1. Ksendzyk, G.V., Frumin, I.I., Shirin, V.S. (1964) *Current-supplying mould*. USSR author’s cert. 264427, fil. 19.11.1964 [in Russian].

2. Ksendzyk, G.V., Frumin, I.I., Shirin, V.S. (1969) *Unit for electroslag remelting*. USSR author's cert. 337026, fil. 25.06.1969 [in Russian].
3. Ksendzyk, G.V., Frumin, I.I., Sirin, V.S. (1979) Patentschrift DE 2746256 C3 BR, C21c 5/52. *Ringformige Kokille fur Anlagen zum Electroschlacke — Umschmelzen bzw*. Auftraschweissen von Metallen. Anmeldetag 14.10.1977, Offenlegungstag 19.04.1979.
4. Ksendzyk, G.V., Frumin, I.I., Shirin, V.S. (1981) *Electroslag remelting and surfacing apparatus*. Pat. 4,305,451 US B22D 27/02. Fil. 23.06.1977, Publ. 15.21.1981.
5. Ksendzyk, G.V., Frumin, I.I., Sirin, V.S. (1981) *Electroslag remelting and surfacing apparatus*. Pat. Specification I 566 819 GB, B22D 11/04, B01F 13/08, B22D 23/06. Fil. 13.09.1977, Publ. 09.07.1981.
6. Artamonov, V.L., Kamensky, Yu.M., Toistev, V.I. et al. (1981) Electric erosion of moulds in ESR and their restoration by cladding. *Spec. Elektrometallurgiya*, **45**, 52–55 [in Russian].
7. (1981) *Electroslag metal*. Eds by B.E. Paton, B.I. Medovar. Kyiv, Naukova Dumka [in Russian].
8. Kuskov, Yu.M., Grishcenko, T.I. (2019) Formation of metal pool in current–supplying mould at electroslag process. *The Paton Welding J.*, **4**, 33–36. DOI: https://doi.org/10.15407/tpwj2019.04.07
9. Holzgruber, W., Holzgruber, H. (2000) Innovative electroslag remelting technologies. *MPT Inter.*, **2**, 46–48.
10. Kubin, M., Scheriau, A., Knabl, M. et al. (2016) Investigation of the implication of the current conductive mould technology with respect to the internal and surface quality of ESR ingots. In: *Medovar Memorial Symp. (7–10 June 2016, Kyiv), Kyiv, Elmetroll*, 174–179.
11. Sokolov, G.N., Mikheev, A.N., Pavlov, A.A. (2002) Electroslag cladding in section mould of edges of rolling mill mandrels. *Svarochn. Proizvodstvo*, **6**, 31–34 [in Russian].
12. Holzgruber, W., Holzgruber, H. (1996) *Verfahren zum Umschmelzen von Metallen Zulinem Strang sowie Vorrichtung da fur*. Pat. EP 0 786 531 A1 Eeuropasches Pat. C 22B 9/18, B 22 D 23/10. Anmeldetag 29.01.1996, Offenlegungstag 21.12.1996.
13. Holzgruber, W., Holzgruber, H. (2000) *Wassergekuhlte Kokille fur das Stranggiessen oder Electroschlackeumschmelzen*. Pat. A. T. 406 239 B Republik Osterreich, B 222D 23/10, C21c 5/52. Anmeldetag 09.04.1996, Offenlegungstag 27.03.2000.
14. Holzgruber, H. (1997) *Wassergekuhlte Kokille zum Herstellen von Blocken oder Strangen sowie deren Verwendung*. Anmeldetag 11.04.1996. Pat. DE 196 14 182 C1BR, C21C 5/52, C22B 9/193. Veroffentlichungstag 31.07.1997.
15. Alghisi, D., Milano, M., Pazienza, L. (2001) The electroslag rapid remelting process under protective atmosphere of 145 mm billets. In: *Medovar Memorial Symp. (15–17 May 2001, Kyiv), Kyiv, Elmetroll*, 97–105.
16. Dubodelov, V.I., Pogorsky, V.K., Shnurko, V.K. et al. (2002) Application of magnetodynamic unit in the technology of electroslag cladding of steel mill rolls using a liquid metal. *Advances in Electrometallurgy*, **4**, 7–8.
17. Tomilenko, S.V., Kuskov, Yu. M. (2000) Special features of melting of parent metal electroslag surfacing in a current-supplying solidification mould. Welding Int., 14(**11**), 893–895.
18. Shevchenko, V.E. (2001) *Electroslag technology in production of modern mill rolls*: Syn. of Thesis for Cand. of Tech. Sci. Degree. Kyiv [in Russian].
19. Netyaga, A.V., Kuskov, Yu.M., Proskudin, V.M. et al. (2021) Formation of a layer of high-chromium cast iron in current-supplying mould of a square cross-section at electroslag surfacing. *Suchasna Elektrometal*., **4**, 16–19. DOI: https://doi.org/10.37434/sem2021.04.02

CONFLICT OF INTEREST

The Authors declare no conflict of interest

CORRESPONDING AUTHOR

V.A. Zhdanov
E.O. Paton Electric Welding Institute of the NASU
11 Kazymyr Malevych Str., 03150, Kyiv, Ukraine.
E-mail: vovik19821982@ukr.net

SUGGESTED CITATION

Yu.M. Kuskov, V.M. Proskudin, V.A. Zhdanov, L.L. Okopnyk (2022) Current-supplying mould in electroslag technologies. *The Paton Welding J*., **7**, 35–38.

JOURNAL HOME PAGE

https://pwj.com.ua/en

Received: 19.05.2022
Accepted: 15.09.2022