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METABK 55(3) 503-506 (2016)
UDC – UDK 669.17.004.16:669.187:666.88:621.36=111

IRON LOSS IN HIGH-POWER ARC STEELMAKING FURNACES

Received – Primljeno: 2015-11-05
Accepted – Prihvaćeno: 2016-02-28
Review Paper – Pregledni rad

There is considered the power operating mode of a high-power arc steelmaking furnaces (ASMF) in the period of the flat bath. It is revealed that electric energy is mainly spent for heating and overheating the foamed slag. Heat transferring from slag to metal is carried out by the convective agitation of the bath. For agitation there is used intensive purging of the bath with oxygen that causes increased iron losses with the running foamed slag. There are noted the negative points of working with the foamed slag. It is recommended to expand R&D in the field of optimizing the power operating mode of high-power ASMF.

Key words: iron, loss, arc steelmaking furnace, slag, heat transfer

INTRODUCTION

Smelting a semi-product in high-power ASMF consists of two periods. One of them is melting, the second one is oxidizing or the period of the flat bath. Iron is lost in each of these periods. Special attention is paid to the analysis of the causes of iron loss in the period of the flat bath.

The present day technology provides performing melting at the high constant active power for both periods, with long arcs, rather small values of current of arcs and at the values of the power factor (λ) approaching 0,87.

The fire-resistant lining of the ASMF slopes is protected from the arcs direct radiation by the metal furnace burden (the melting period) and the foamed slag (the flat bath). This technology came to domestic metallurgy together with a set of the import steel-smelting equipment and did not practically change within the next years.

The ASMF operation by this technology caused considerable iron losses with the foamed slag. Concentration of iron oxides in slag is great and reaches 52 % [1]. This foamed slag is spontaneously removed from the furnace. The compelled deep purge of the bath with oxygen which purpose is intensive agitation of metal and slag is the main cause of the slag high oxidation. Without agitation it would be almost impossible to transfer quickly the overheated slag to the metal bath. In the period of the flat bath electric energy is spent mainly not for metal heating but for slag heating.

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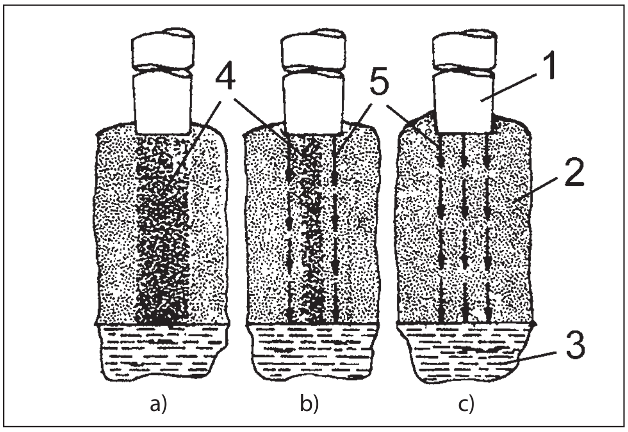
EXPERIMENTAL PART

Equipment and tools

The publication of the lining protection against radiation of the arcs with the foamed slag appeared in 1986 [2]. The authors of this work suggested that between an electrode and metal in the foamed slag there can burn an electric arc, or be supported arc-free charge (current passing through slag as in electroslag melting), or can exist one and another in combinations (Figure 1). The options of current passing through the foamed slag were considered individually for one electrode out of its connection with the other electrodes of the three-phase furnace. In this publication there is presented the general phrase that the type of the discharge will be defined by electric conductivity of slag. In the work there are not a word is said of the possibility of the discharge



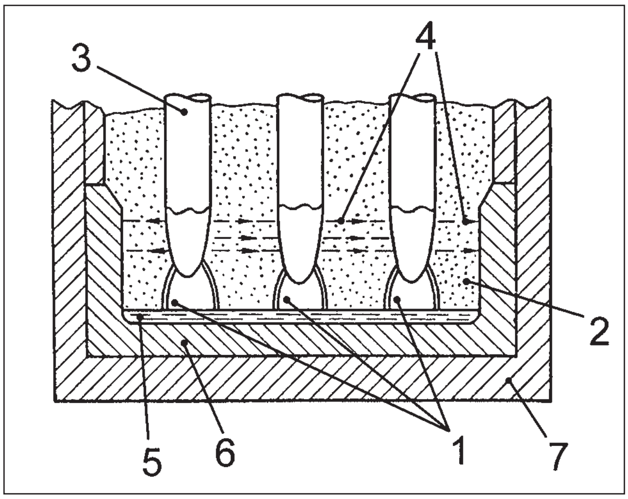
a) – completely arc discharge in slag; b) – arc discharge and partial heating by resistance; c) – complete heating by resistance: 1 – electrode; 2 – foamed slag; 3 – metal; 4 – electric arc; 5 – lines of current arc-free passing

Figure 1 Possible options of current lines passing through the ASMF foamed slag according to [2] passing not through metal but directly between electrodes through the foamed slag. Work [2] in foreign literature is still referred to [3, 4]. However, any additional data of the nature of electric current passing through slag are not provided. In work [5] there was considered the possibility of reducing the length of the arc in the foamed slag by means of impacting the power failure gradient in the arc. It was recognized that it is impossible by technological measures to execute reducing the length of the arc.

Undoubted interest is represented by the latest works of domestic authors [6, 7] in which there are studies the deviations of the alternating current arc burning in the foamed slag from the sinusoidal law. At this there is made an assumption of possible shunting of electric current directly between the electrodes. There is noted a noticeable decrease in the amplitude of the highest current harmonicas and the arc voltage that is characteristic of current passing not through the arc but through ohmic resistance. There is made an analogy to the operation of arc ferroalloy furnaces (AFSF) where shunting of current between electrodes through the furnace burden and slag is widespread. When smelting carbonaceous ferromanganese, about forty percent of the thermal electric power are allocated between the electrodes in the furnace burden and slag under the law of resistance, and the other part of energy is emitted in the arcs [8]. The diagram of currents distribution is presented for AFAF in Figure 2 on the materials of the textbook by A.D. Kramarov and A.N. Sokolov [9]. The authors note that in certain cases emission of heat due to the arc-free current passing 85 % of the electric power consumption.

A.V. Yegorov [10] believes that in the FAF there are 3 chains of current: 1) the electrode end face - the bath (arc); 2) the side surface of the electrode – lining – the bath; 3) the side surface of the electrode – the side surface of the next electrode. At this the 1 and 2 chains are a “star” electric circuit, and 3 is a “triangle”. If these regularities are right both for the foamed slag and for the ASMF, the raised thermal emission in the top horizons of slag is inevitable. What defines the possibility of the slag overheating? Here is expedient the abstract from work [10]: “In actual practice of the FAF the electric field configuration and current distribution depend on the diameter of the electrode, the gap between the electrodes, the gap between the electrode and the bath, the depths of the electrode immersion in the furnace burden, the furnace burden layer heights, as well as electric-and-physical properties of the non-uniform electrowire environment of the FAF bath”.

Similar shunting of the electric arc (a “triangle” circuit) is quite possible in heavy-duty ASMF. The secondary linear voltage of the ASMF is several times higher than in the FAF, and slag is electricity conductive. The conductivity of slag is provided with high concentration of iron oxides, the presence of metallic beads and particles of coal dust. Unfortunately, the studies of electric current distribution in the foamed ASMF slag are not known, but there are measured the temperatures of the slag and metal under it.



1 – zone of electric arc; 2 – burden; 3 – electrodes; 4 – lines of arc-free current passing; 5 – metal bath; 6 – coal blocks; 7 – external lining [9]

Figure 2 View of current distribution in the ferroalloy furnace according to [9]

RESULTS AND DISCUSSION

In the super-power ASMF the average temperature of slag is about 200 ^{0}C higher than the metal temperature [6]. Slag temperature near the electrodes reaches 1 800 ^{0}C and there are no data of the slag temperature between the electrodes. The slag overheating is still aggravated with the provision of the operating technology ordering to work within the flat period of the bath at high active power with small currents, therefore with long arcs. The warmth of the overheated foamed slag can be transferred to metal only by intensive convective agitation of the bath.

When using the foamed slag for smelting a semi-product there were revealed some other negative points:

1 Coal dust in the gases departing from the working space of the furnace complicates the operation of gas-purifying devices [11].

2 Coal dust in the deleted slags continues to generate CO and CO_2 in the shop.

3 The foamed slag possesses small density and small thermal capacity. Considerable efforts for agitation to transfer warmly the overheated slag to metal are required.

4 The main means of the slag agitation and metal serves the deep purging the metal bath with oxygen that leads to the increased iron oxidation.

5 When foaming slag the volume is by 1,5 times increased and the heat content of flue gases increases. At this thermal losses with flue gases become the largest cause of thermal losses of present day ASMF [12, 13].

6 Slag foaming increases the specific mass of greenhouse gases (kg CO_2 / t STEEL) that wors-

ens the ecological certificate of metallurgical production [14].

7 The overheated foamed slag causes metal rephosphorization before the output that complicates removal of phosphorus to concentrations lower than 0,010 % [6].

8 The carrier of the powder of carbonaceous materials there serves dried air. At the air contact with metallic beads in the overheated foamed slag and with the metal bath it is necessary to be afraid of increasing the concentration of nitrogen in the semi-product.

9 The operation of the ASMF at the constant active power within melting and at the flat bath demands numerous changes of the number of transformer windings and the throttle which number of switching reaches 1 000 per day [15]. The control of the mode of switching is under exclusive authority of the invited foreign experts [16].

10 There arise additional problems with cleaning and useful application of the solidified foamed slag.

From the moment of publication of the article of the advantages of slag foaming [2] there passed 29 years. In the period of the flat bath the foamed slag reliably protects the lining of slopes from powerful radiation of long arcs. The warmth of electric discharge is transferred to the bath, but it is mainly acquired by the foamed slag. There are no still proofs that the accepted technology of high power long arcs and the foamed slag provides fast metal heating. There are opinions that the work with short arcs buried in the metal bath at the same power will heat metal twice faster. The technology of using short arcs was applied at the initial stage of developing the ASMF ultrahigh power.

What can be the grounds to return to short arcs buried in metal? First of all, the direct fast heating of the metal bath. In this method of operation there also arise negative phenomena. First of all, the operating mode with the increased values of arcs current leads to increasing the electrodes material losses due to its dispersion. Secondly, there is needed the work with the lowered values of power factor λ. At long arcs the λ value is maintained at the level close to the maximum of coefficient of radiation (Rf) which maximum is provided at $\lambda = 0,87$. Owing to the unstable burning of a long arc they practically work with somewhat greater values of current and the lowered $\lambda = 0,76 – 0,81$ values. The operation with the maximum value of the coefficient of heating intensity (CHI) is possible with $\lambda = 0,61$ practically at 0,63 – 0,65. These two negative factors can be compensated by reducing the duration of the metal bath heating, decreasing iron losses, as well as partial elimination of the negative points of the foamed slag stated above. The intensive purge of the a semi-product with oxygen can be replaced with purging with an inert or other gas through the ground lances.

CONCLUSIONS

The foamed slag was introduced as a security measure of the fire-resistant lining of the furnace slopes. In the next years there significantly changed the structure and properties of the fire-resistant material of slopes. There were developed and introduced density periclase-carbonaceous refractories [16, 17]. The water-cooled panels of walls were lowered that was promoted by the widespread practice of the ASMF operation. In the slag composition there was increased the oxide of magnesium concentration. Fire-resistant slopes of the ASMF increased their resilience to the direct radiation of electric arcs.

It do not suggest in the technology of the flat bath to refuse using the foamed slag, long arcs and high active power. Nevertheless, there is an alternative of optimizing the technology. It would be necessary to pay attention to the need of studying in the field of power operating modes of heavy-duty ASMF on the operating units with the involvement of specialists of domestic engineering schools.

REFERENCES

[1] Bigeyev V. A. Slag oxidation in present day arc steel-smelting electric furbaces/V. A. Bigeyev, A. E. Molofeev, A. V. Panteleev, A. N. Fedyanin, A. V. Brusnikova//Messenger of SUrSU, series Metallurgy. (2010) 34, 4 – 7.

[2] Ameling D. Untersuchungen zur Schaumschlackenbildung im Elektrolichtbogenofen / D. Ameling< I. Petri< M. Sittard< W.Ullrich, I. Wolf //Stahl und Eistn. 106 (1986), 11, 625 – 630

[3] Peter M. Foaming slags in the course of melting in arc furbaces/M. Petter, K. Koch, Ya. lamut, M. Yukhart //Even metals. (2000), 3, 26 – 33.

[4] Merts M. New data of using foamy slag when smelting high-chromium steels/M. Mertz, T. Piper, V. Stein, T. Rat, G. Harl, A. Sax//Ferrous metals. (2006) 6, 46 – 49.

[5] Alameddin S. Work on superlong arcs and existing restrictions when smelting steel in arc furnaces of alternating current//S. Alameddin, H-and. de la Penia, U. Adams, B. Boumen, N. Lyugo.//Ferrous metals, November, 2006, p. 36 – 40.

[6] Nekrassov I. V. Development of the rational mode of melting a steel semi-product in heavy-duty arc electric furnaces // Abstract of the thesis for the academic degree of Cand.Tech.Sci., Yekaterinburg, IMET URO, 2010, 24 p.

[7] Volkodayev A.N. Using amplitudes of the highest harmonicas in arc voltage of high-power arc furnace for controlling power process//A. N. Volkodayev, N. V. Evseev, O. K. Tokovoy//Steel, 2000, No. 2, p. 24 – 27.

[8] Gassik M. I. Theory and technology production of ferroalloys / M. I. Gasik, N. P. Dyakishev, B. I. Emlin.// Metallurgy, (1988), 784

[9] Kramarov A. D. Electrometallurgy of steel and ferroalloys / Textbook/ A. D. Kramarov, A. N. Sokolov//Metallurgy, 1976, 376 p.

[10] Yegorov A.V. Electromelting furnaces of ferrous metallurgy: Textbook for HEIs/Metallurgy, 1985, 280 p.

[11] Roshchin V.Ye. Electrometallurgy and metallurgy of steel: Textbook/V.E.Roshchin, A. V. Roshchin//Chelyabinsk, Prod. Center pf SUrSU, 2013, 572 p.

[12] Sutyagin K. L. Technique of determining power of thermal losses in arc steel-smelting furnaces / K. L. Sutyagin, V. P. Karasev.//Electrometallurgy (2006) 3, 36 – 42.
[13] Keung R. Continuous analysis of flue gases and power balance in electric steel-smelting production / R. Keung, J. Deng.//Ferrous metals, September (2005) 46 – 50.
[14] Shevelyov L. N. Methodological bases of inventory of greenhouse gases in ferrous metallurgy of Russia/L.N. Shevelyov//Steel (2007) 4, 97 – 101.
[15] Yevdokimov S. A. Control of technical condition of of the transformer RPN of heavy-duty arc steel-smelting furnace/ Messenger of SUrSU, Power series, 14 (2014) 1, p. 22 – 30.
[16] Nikolayev A. A. Increasing the overall performance of a heavy-duty arc steel-smelting furnace due using the system of diagnostics of melting stages on the highest harmonicas of current arcs/A.A.Nikolayev, A.V. Anufriyev, G. P. Kornilov, V. S. Ivekeyev, I. A. Lozhkin//Proceedings of the 28 international Sci. Prac. Conf «Technical Science: from Theory to Practice», Novosibirsk, October, 2013.
[17] Kashcheyev I. D. Oxide carbonaceous refractories/ I.D. Kashcheyev// Intermet Engineering Journal, 2000, 265 p.

Note: Responsible translator into English is N.M. Drak, KSTU, Karaganda, Kazakhstan