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IMPROVEMENT OF METHODS FOR SEMI-FINISHED CARBON PRODUCT TAPPING FROM THE BASIC OXYGEN FURNACE (BOF)

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The article considers the experience of optimizing the slag adjustment mode in the Basic Oxygen Furnace (BOF) and reducing the proportion of oxide non-metallic impurities in steel. The article presents the results of a research on the separation of slag from metal during the starting period of carbon semi-product tapping, on the elimination of an emergency situation when the hole is shut up at any degree of slag viscosity, the use of the device at any tap hole diameter after the heat, the simplicity of the design. The use of the device makes it possible to increase the durability of the taphole lining, reduce repair costs, and improve the quality of steel by reducing non-metallic impurities. The innovative devices proposed by the author can be useful for metallurgical enterprises.

Keywords: steel, BOF, carbon product, oxides, slag separating

INTRODUCTION

The current stage in the development of metallurgy is characterized by a significant expansion of metal products range, it’s constant qualitative and quantitative growth, an increase in production volumes and an increase in the operational properties of steel, while reducing the metal intensity of finished products.

The development of new branches of engineering, as well as the intensification of the existing processes of physical and chemical technology for the production of materials and products require a sharp increase in the quality of metal, the level of performance, and the reliability of products.

The purpose of this work is to develop the devices, which allow the most complete separation of the «primary process slag» during the starting, intermediate and final periods of carbon semi-finished products tapping into the steel-pouring ladle.

STATEMENT OF BASIC MATERIALS

The value of the equilibrium constant, as well as the values of carbon and oxygen concentration, respectively (C) * (O), depend on temperature. In practice, Vacher and Hamilton equations are used [1].

When the concentration of carbon is up to 1 %, and oxygen is up to 0,08 %, then the activity coefficients equal 1. If we assume that the gas phase consists of CO only, that is, $P_{CO} \approx P_{total}$, then at constant T and P_{total}, the product (% C) • (% O) will be permanent. Thus, at a pressure of P_{CO} = 101,3 kPa and at a temperature of 1 600 °C, the equilibrium constant equals 403, and the product (% C) * (% O) = 0,0025, according to the Vacher-Hamilton equation. The resulting ratio shows that the equilibrium oxygen concentration in iron is inversely proportional to the carbon content. The same tendency is observed in production conditions, where the actual oxygen content in the metal (O) is always higher than the equilibrium one.

The relationship of the equilibrium oxygen content of carbon concentration in the metal at 1 600 °C and normal pressure is represented by Vacher-Hamilton equation; the actual values of these parameters are higher due to a variety of factors (see Figure 1).

Lime is the main fluxing material for refining metal from sulfur and phosphorus, the consumption of which is 70 - 150 kg/t of steel, and here iron oxide is the main oxide that assists the assimilation of lime by the slag melt.

Figure 2 shows the distinctive relationships of the distribution coefficients of phosphorus between the metal and slag for different basicity depending on the presence of iron oxide and lime, the quality of which largely determines its consumption and refining proper-

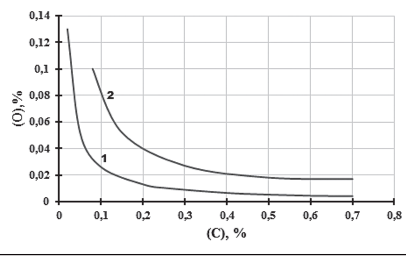

Figure 1 Connection of metal carbon with oxygen concentration at the end of refining
1 – equilibrium values according to Vacher-Hamilton
2 – actual values of carbon and oxygen in metal

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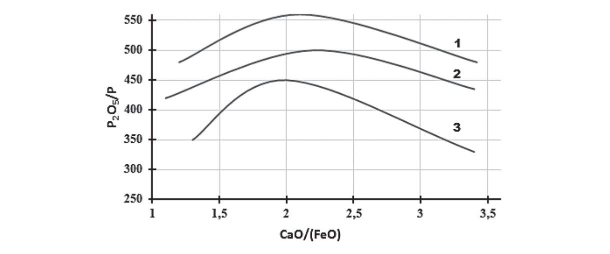


Figure 2 Dependence of the distribution coefficient of phosphorus on the CaO / (FeO) ratio

1 – basicity $B = \frac{CaO + MgO}{SiO_2 + P_2O_5}$ = 2,8÷3,2;

2 – basicity $B = \frac{CaO + MgO}{SiO_2 + P_2O_5}$ = 3,21÷4,0;

3 – basicity $B = \frac{CaO + MgO}{SiO_2 + P_2O_5}$ = 2,4÷2,79.

ties, namely the reactivity (maximum temperature during quenching, quenching time), ignition losses, the presence of useful and harmful impurities, the presence of incompletely burnt material. In addition to this main fluxing material, there is limestone, fluorspar, fired magnesite, dolomite, and others.

At a number of metallurgical plants, when tapping metal from a furnace or BOF, a simpler method of separating the slag from the metal is used: the ladle with the metal is removed from the unit at the moment the slag appears; this method, however, does not provide stable results and comes with metal losses. The problem of the final slag separation remains one of the most important [2].

The [3-4] papers provide the devices for separating the melts, but they have some disadvantages.

The stopping device proposed by the authors [4] is distinguished by the opportunity of immersing the device to any depth in the working space of the BOF and electric furnace, reliably separating the slag at any angular working inclination of the unit for draining metal into the ladle and the location of the tap hole axis relative to the horizontal.

It is obvious that the other schemes and sets of elements of a device for closing the taphole of a steel-making unit can be used in this proposal, for instance: using bodies made of a metal bar with a washer; seamless, multilayer and strip pipes, etc. The proposal is illustrated by Figure 3.

Figure 3 shows the blocking unit of the device for separating slag and metal melts. The taphole section 1 is installed on the refractory materials 2 for the entire length of the unit lining 3 and the taphole box 4 and is wedged with a special brick. Zigzag guides 5 are welded to the vertical sides of the tap box.

The locking element 6 fits into the recess with a three-arm fork device. Based on the example of a BOF unit, the device works as follows:

The tests were carried out on a 300 t-BOF, the working layer of the tar-dolomite lining durability was 203 melts. The length of the combined taphole section was

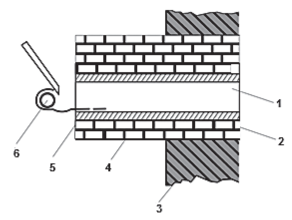


Figure 3 The devices for the separation of slag and metal melt
1 – taphole section, 2 – refractory materials,
3 – unit lining, 4 – tap box, 5 – zigzag guides,
6 – locking element

1 400 mm, the diameter of the taphole was 160 mm, and the durability of the section was 9 heats. The period of release of 300 tons of metal was 11 minutes 20 seconds (according to the technological instructions of the enterprise, the duration of the tapping from high-capacity BOFs is 5-12 minutes).

The inclination angle between the vertical axis and the axis of the BOF taphole is 60 degrees. A steel pipe 210 cm long, with an outer diameter of 15,7 cm, a wall thickness of 1,8 mm with a rolled head part is used as a slag separating element.

After the end of the smelting process, the BOF is tilted towards the working platform to a level that provides visual observation of the tap hole.

The dead-bottom pipe is pushed into the tap hole flush from the front side of the tap hole and 50 cm into the BOF working space, after which a locking element in the form of a cylinder made of wood with a diameter of 70 mm is installed with a fork device along the descent into the recess until it stops. Subsequently, when the BOF is tilted until the tap hole takes up the drain position, the pipe rests against the locking element, and after 2 seconds the pure metal without slag is poured into the steel-pouring ladle.

Besides the above-mentioned pipe, a perforated, braided pipe for high-pressure lines and other shut-off devices may be used, in particular using a rod and a tube of small diameter, but with a washer attached to the taphole diameter and stabilizers alignment. The locking element also does not seem to be in short supply at any stable profile - a circle, a square, a hexagon, etc.

The use of the device makes it possible to cut off the primary steelmaking slag most completely, increase the operational reliability of the device, and improve the technical and economic indicators of the steelmaking process [4].

In the current and final periods of tapping the melt from the BOF (5 – 25 % of the time before the end of tapping), the metal level above the tapping zone decreases as a result of the formation of a crater funnel, where the metal phase is mixed with the slag by injection, thereby increasing the proportion of non-metallic impurities in the finished steel.

There is an invention for separating molten metal and slag being in the form of a whirligig dart with a density greater than the density of the slag (1,7-3,5 g/cm^3), but less than the density of the metal (7,8 g/cm^3) at the level of 4,2-6,6 g/cm^3 floating at the metal-slag interface, and upon completion of the metal drain, it seals up the tap hole and separates the slag [5].

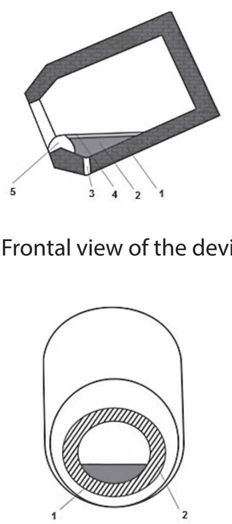
The complexity of using this device lies in the fact that it often "floats away" from the predetermined zone when the working layer of the BOF lining is heated, it is welded with the taphole section of the lining, creating an emergency, as well as the high cost of the manipulator for transportation and dropping the whirligig dart to the desired point, which is difficult in conditions of limited visibility, dynamics of dust and gas flows, high radiation, since the temperature of the metal and slag during the release period is at the level of 1 600-1 680 °C.

The most used option for reducing the mass of slag involved in the metal flow is to increase the level (layer thickness) of the metal above the tap hole and remove the slag layer as high as possible. In the prototype design of the BOF, the middle and bottom part is made conical to increase the depth of the metal above the tap hole when the unit is tilted [6].

To prevent the above-mentioned event, a special technical solution is proposed.

The technical result is achieved by the fact that in order to improve the quality of steel smelted by the BOF by reducing the proportion of non-metallic impurities from the molten slag during the period of metal tapping into the neck area, the solidifying slag is deposited, creating a false threshold in the form of a flat segment.

Figure 4 shows the frontal and side views of the above mentioned elements:



a) Frontal view of the device

b) Side view of the device

1 – BOF lining; 2 – metal smelt; 3 - taphole;
4 – melted slag; 5 – false threshold.

Figure 4 Slag separating device

Upon the appearance of the first signs of slag in the flow, which is determined visually and using the infrared radiation camera, the flow is blasted by the maximum speed of the BOF turning and the unit is put into a vertical position.

Deposited dam is pushed with a scoop into the working space of the BOF, mixing it with separated slag, bringing it to the level of 7-14 % MgO in the mixture and a gaseous nitrogen stream, the mixture is applied to the lining of the BOF, forming a soot resistant to high temperatures and positive values of mechanical properties.

08 PS Steel ("semi-killed") is brought to standard parameters on a ladle furnace and casted on a continuous casting machine.

The presented method of metal production from the BOF allows improving the quality of steel and reducing the waste of manganese by 2,8 %, for silicon by 3,1 %, and for aluminum by 3,7 % [7].

CONCLUSION

The use of the devices allows separating the technological BOF slag, improving the quality of steel and increasing the lining durability, bringing the concentration of the periclase component to the level of 7-14 % in the slag, and reducing the consumption of deoxidizers and alloying components. When using the device, manganese waste was reduced by an average of 4,2 %, silicon by 3,7 %, aluminum by 4,4 % at Arcelor Mittal Temirtau JSC enterprise, and the proposed method allows to reduce the proportion of non-metallic inclusions by 1,2 %.

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