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THE METAL REFINING PROBLEM AND TECHNICAL SOLUTIONS FOR THE ACTIVE SLAG FORMATION IN INDUCTION FURNACES

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Abstract

In induction crucible furnaces (ICF), the protective (coating) properties of slag play an important role. The permeability of slags in relation to the components of the atmosphere - oxygen, nitrogen and hydrogen largely determines the gas saturation of the metal and the development of oxidation processes. Mass transfer processes are associated with the diffusion mobility of impurities, the viscosity of slag, and its composition. Taking into account the specifics of specific processes, slags can also perform some other functions - maintaining a given thermal regime in the furnace. Slags, as a refining material, in the process of metal smelting in ICF have not yet found wide application in metallurgical practice.

Keywords: metals refining, steel smelting, deoxidation technology, casting technology, induction crucible furnaces, ferrostatic pressure, slags, cast parts.

1. Introduction

Typically, slags in ICF with the main lining do not perform such functions as oxidation, reduction, desulfurization and dephosphoration. In the process of metal melting, slags in the furnace are formed as a result of oxidation of the charge components and the lining materials of the crucible. These slags are usually removed at the end of melting and “fresh” ones are brought from the battle of glass and quartz sand for acid furnaces and from lime and fluorspar for furnaces with a basic lining. The main purpose of these slags is to protect liquid metal from interaction with the atmosphere and to reduce the loss of energy emitted by the surface of the metal mirror. Significant energy losses through the slag surface lead to low fluidity and large temperature differences in height (up to 1200 K).

Slags, as a refining material, in the process of metal smelting in ICF have not yet found wide application in metallurgical practice. This is primarily due to the low reactivity of the slags, which are heated only by heat transfer in the contact zone with the metal surface, the small size of the metal–slag contact surface, and the cooling of the slags by the crucible lining. On the basis of which, it is often concluded that the refining capacity of slags in ICF is insufficient, and accordingly, an increased requirement is imposed on the metal charge, in terms of the content of elements such as phosphorus and sulfur. Refining of metals in ICF according to traditional schemes is practically absent.

Electromagnetic forces and the electrodynamic circulation of metal caused by them deform the surface of the bath, which acquires a convex meniscus with a height of Dm. As a result, the slag covering the metal surface flows down to the crucible wall, and as a result, more slag-forming mixtures have to be given.

Slag accumulating at the crucible wall and chemically interacting with the lining corrodes it for a longer length than with a flat metal surface. In addition, during metal circulation, there is an increase in exogenous slag particles and products of destruction of the crucible lining in the volume of metal. Electromagnetic forces in a metal cylinder placed in a cylindrical inductor are directed radially to the axis of the cylinder (in the direction of the energy flow), and the maximum pressure is created by these forces on the axis of the cylinder.

2. Methods

Some of researchers believe that slag during induction melting can participate in the metal refining process, but under certain conditions. Some techniques to increase the activity of slag are described below.

A way to reduce the height of the meniscus. The most common method of reducing the height of the meniscus of the Chm is based on reducing the magnetic field strength in the upper part of the bath, etc., as a result of which circulation near the bath mirror is weakened and suppressed by ferrostatic pressure.

However, the asymmetric arrangement of the inductor relative to the metal reduces heat generation in the upper part of the crucible and complicates the melting of the metal charge (individual pieces of the charge are welded into a solid "bridge" that prevents the descent of the cold charge into the melting zone). Therefore, it is advisable to regulate the electrodynamic circulation during melting by applying either a mechanical lowering of the inductor level by raising the crucible or lowering the inductor, or an electrical lowering of the inductor level by disconnecting the upper turns.

3. Results and Discussion

Removal of harmful impurities by oxidation. Carbon oxidation, removal of phosphorus and sulfur in ETC with the main lining can be carried out at high speed. It would seem that the shape of the bath in the form of a crucible should make it difficult to carry out the operation of cleaning the bath from impurities, due to the small surface of contact of metal with slag. In reality, the intensive circulation of metal completely compensates for this disadvantage. Diffusion processes in ICF are faster, reaction products are intensively brought to the surface and removed, i.e. reactions can proceed quite fully.

It would be possible to remove harmful impurities from the liquid bath in the ICF with the main lining within a few minutes, but in practice it is difficult to do this, since a large amount of iron oxide will cause the bath to boil too vigorously and metal and slag to splash out of the furnace. Based on this, iron ore concentrate is planted in small portions, each time after calming the bath. In addition to iron ore concentrate, which is usually consumed in an amount of 3...5% of the mass of the metal charge, about 2% lime and 0.2% fluorspar are also added, which is necessary to increase the fluidity of the slag. The lower the viscosity of the slag, the more energetic the phosphorus removal process is. Such a slag has a very successful effect on a liquid metal bath and in 15 minutes allows it to reduce the carbon content by 70... 80%, phosphorus — by 50...60%. Along with this, silicon also burns out by 40...50% and part of manganese. The process of burning out impurities can be even more intense if the slag surface is protected from cooling by closing the crucible with a vault made of heat-insulating bricks, or by heating the slag.

During the metal refining period, the inclusion of a plasmatron allows heating the slag, increasing its reactivity, which is impossible in ICF.

A.M. Samarin cites a change in the content of carbon and phosphorus in the process of steel smelting carried out with oxidation in IST-0.3, with a power of 100 kW and a current frequency of 500 Hz. When using slag consisting of 51.8% CaO and 12.9% SiO_2, the phosphorus content in 15 minutes was reduced from 0.130 to 0.020%. During the melting process, the crucible was covered with a vault of heat-insulating bricks, which protected the slag from cooling.

In the process of another experimental melting, after holding the molten metal under oxidizing slag for 20 minutes, the carbon content decreased from 2.7 to 1.7%, and in the next 35 minutes – to 0.14%. Thus, the rate of carbon oxidation was 3% per hour. In chipboard, this speed is 5 times less.

Faster and more efficient oxidation of impurities can be achieved in the ICF with the main lining, if air is blown onto the surface of the bath. In this case, silicon and manganese can be almost completely removed from the bath, and the carbon and phosphorus content can be increased to 0.02%. The method of air injection, in comparison with ore oxidation, more effectively increases the rate and degree of burnout of impurities.

The corrosion of the crucible wall is also reduced. To reduce the corrosion of the crucible wall during the main lining, it is recommended to add 15 to the slag...20% periclase of the slag mass. At the same time, the slag does not lose its fluidity. Naturally, the larger the area of contact of the metal with the slag, the higher the temperature of the slag and the smaller the depth of the bath, the higher the rate of purification of the metal from impurities, therefore, the higher the mechanical properties of the resulting product.

Heating of slag by plasma arc. When installing a plasmatron in the furnace vault, it becomes possible to heat the slag to the temperature required for metallurgical processes at the metal-gas phase-slag boundary.

4. Conclusion

The additional use of a DC arc burning between the graphite electrode and the charge allows you to quickly melt a vertical “well" in it. Individual pieces of the charge forming the inner walls of the “well” are melted and electrically bridged, as a result of which the total electrical resistance of the charge decreases, and the power transmitted to it from the inductor increases sharply. The duration of the melting period is reduced by 20...30% and reduction of specific electricity consumption.

The above technical solutions once again show the possibility of the formation of active slag during the smelting of steel in the ICF and the use of relatively cheap scrap with a reduced content of silicon, manganese and an increased content of sulfur and phosphorus as a charge.

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