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

Tursunov Nodirjon Kayumjonovich
Ph.D., head of the Department of Materials Science and Mechanical Engineering,
Tashkent State Transport University, Tashkent, The Republic of Uzbekistan,
e-mail: u_nadir@mail.ru

Toirov Otabek Toir ugli
Ph.D. student of the Department of Materials Science and Mechanical Engineering,
Tashkent State Transport University, Tashkent, The Republic of Uzbekistan
e-mail: tv574toirov@mail.ru

Erkinov Sultonbek Muzaffar ugli
Assistant of Tashkent State Technical University named after Islam Karimov
Tashkent, The Republic of Uzbekistan

Kuchkorov Lochinbek Akhmadjon ugli
Ph.D. student of the Department of Materials Science and Mechanical Engineering,
Tashkent State Transport University, Tashkent, The Republic of Uzbekistan
e-mail: telekommunikatsiya@gmail.com

Annotation

In the foundry industry, induction crucible furnaces (ITF) are widely used, which are very effective for the production of various steel grades. Their features make it possible to obtain the required chemical composition of steel with minimal loss of alloying materials. However, the limited possibilities for refining from harmful impurities dictate certain requirements for the charge, which affects the cost of the final product.

The expansion of the technological capabilities of ITF can be achieved by increasing the efficiency of the slag mode. Various methods of intensifying the refining process were tested, which include blowing with slag mixtures, using a plasma torch to heat the slag, and other ways to increase its refining capacity. However, the methods studied and recommended have not found wide application, and ITF continues to be used mainly as a remelting unit operating on a pure charge. In this connection, the development of technological methods, in order to improve their refining properties of slag, is a very urgent task.

Keywords: Induction crucible furnace, slag, desulfurization, dephosphorization, impurity, carbon, phosphorus.

Introduction

In crucible induction furnaces (ITF), the protective (covering) 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 the 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.
Usually, slags in ITF with a main lining do not perform such functions as oxidation, reduction, desulfurization and dephosphorization. In the process of melting metal, slags in the furnace are formed as a result of the oxidation of the components of the charge and the lining materials of the crucible. These slags are usually removed at the end of the melt and brought "fresh" from broken 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 the 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 along the height (up to 1200 K).
Slags as a refining material in the process of metal smelting in ITF have not yet found wide application in metallurgical practice. This is primarily due to the low reactivity of slags, the heating of which occurs only due to heat transfer in the zone of contact with the metal surface, the small size of the metal-slag contact surface, and the cooling of slags by the crucible lining. On the basis of this, a conclusion is often made about the insufficient refining capacity of slags in the ITF, and, accordingly, an increased requirement is placed on the metal charge, in terms of the content of such elements as phosphorus and sulfur. There is practically no refining of metals in the ITF according to traditional schemes.
Electromagnetic forces and the electrodynamic circulation of the metal caused by them deform the surface of the pool, which acquires a convex meniscus with a height of Δh_m. As a result, the slag that covers the surface of the metal flows down to the wall of the crucible, and as a result, more slag-forming mixtures have to be given.
The slag accumulating at the wall of the crucible and chemically interacting with the lining corrodes it to a greater extent than with a flat metal surface. In addition, during the circulation of the metal, there is an increase in exogenous slag particles and

destruction products of the crucible lining in the volume of the 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.

A number of researchers believe that slag during induction melting can participate in the metal refining process, but under certain conditions. The following describes some techniques to increase the activity of the slag.

Method for lowering the height of the meniscus. The most common way to reduce the meniscus height Δh_m is based on a decrease in the magnetic field strength in the upper part of the ITF bath, as a result of which the circulation near the bath mirror is weakened and suppressed by ferrostatic pressure.

However, the asymmetric location of the inductor relative to the metal reduces heat generation in the upper part of the crucible and makes it difficult to melt the metal charge (individual pieces of the charge are welded into a solid "bridge" that prevents the cold charge from descending into the melting zone). Therefore, it is advisable to regulate the electrodynamic circulation in the course of melting, using either a mechanical lowering of the level of the inductor by raising the crucible or lowering the inductor, or an electrical lowering of the level of the inductor by turning off the upper turns.

Removal of harmful impurities by oxidation. Oxidation of carbon, removal of phosphorus and sulfur in the ITF with the main lining can be carried out at a high speed. It would seem that the shape of the bath in the form of a crucible should make it difficult to clean the bath from impurities, due to the small contact surface of the metal with the slag. In reality, the intensive circulation of the metal completely compensates for this shortcoming. Diffusion processes in the ITF are faster, the 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 ITF with the main lining within a few minutes, but in practice this is difficult to implement, since a large amount of iron oxide will cause the bath to boil too vigorously and splash metal and slag out of the furnace. Based on this, the iron ore concentrate is added in small portions, each time after the bath has calmed down. In addition to iron ore concentrate, which is usually consumed in an amount of 3 ... 5% by weight 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 vigorously the process of phosphorus removal proceeds. Such a slag has a very successful effect on a liquid metal bath and in 15 minutes it allows to reduce the carbon content in it 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 surface of the slag is protected from cooling by covering the crucible with a vault made of heat-insulating bricks or by heating the slag.

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

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

During another experimental melting, after holding the molten metal under the 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 an arc steel-smelting furnace (SSF), this speed is 5 times less.

Faster and more efficient oxidation of impurities can be achieved in ITF with a main lining if air is blown onto the surface of the bath. In this case, it is possible to almost completely remove silicon and manganese from the bath, and bring the content of carbon and phosphorus to 0.02%. The air injection method, compared with ore oxidation, more effectively increases the rate and degree of impurity burnout.

Corrosion of the crucible wall is also reduced. To reduce the corrosion of the crucible wall with the main lining, it is recommended to add 15 ... 20% periclase to the slag by weight of the slag. The slag does not lose its fluidity. Naturally, the larger the contact area 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.

Slag heating by plasma arc. When installing a plasma torch in the roof of the furnace, it becomes possible to heat the slag to the temperature required for carrying out metallurgical processes at the metal-gas phase-slag interface.

The additional use of a direct current arc burning between the graphite electrode and the charge makes it possible to quickly melt a vertical “well” in it. Separate pieces of the charge forming the inner walls of the “well” are melted and electrically bridged, as a result of which the overall electrical resistance of the charge decreases, and the power transmitted to it from the inductor increases sharply. There is a reduction in the duration of the melting period by 20 ... 30% and a decrease in the specific power consumption.

The above technical solutions once again show the possibility of active slag formation during steelmaking in the ITF and the use of relatively cheap scrap with a low content of silicon, manganese and a high content of sulfur and phosphorus as a charge.

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