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The Effect Of Acidic Refractory Materials In Electric Furnaces On The Quality Of Molten Metal

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Abstract

This article analyzes the wear of the refractory lining in an induction furnace by considering the thermal conductivity and oxidation level of the internal refractory materials, as well as the addition of various fluxes and ferroalloys to the molten alloy. The study also evaluates how the temperature of the melt influences the rate of lining erosion.

Keywords: induction furnace, alloy, lining, refractory brick, flux, ferroalloy, wear, slag, quartzite, crucible.

Introducton

After gaining independence, significant scientific research has been carried out in our country on the reuse of refractory materials employed in the linings of electric furnaces used in metallurgy [1], industrial complexes, and foundry production, and a number of positive results have been achieved.

In this regard, it is necessary to improve and implement technologies aimed at increasing the service life of furnace linings by restoring worn areas using spent refractory materials and slag separated from alloy compositions. This includes optimizing the ramming regime of furnace linings and standardizing the composition of slag materials used for restoration purposes [2].

Research Methods

Furnaces are classified into acidic and basic processes. The walls of acidic furnaces are made of silica Dinas bricks, and the bottom is lined with quartz powder. Acidic electric arc furnaces are used for producing higher-quality steels. The walls of these furnaces are constructed from Dinas bricks and coated with a mixture consisting of 10% boric acid, 90% quartz sand, and a certain amount of water.

As a flux, limestone is used in basic furnaces, whereas quartz sand or glass cullet is used in acidic furnaces [3]. In electric furnaces with acidic linings, it is relatively difficult to remove harmful elements such as phosphorus (P) and sulfur (S) from the molten steel into the slag during the melting process. Therefore, when melting steel in such furnaces, it is recommended to carefully calculate and control the composition of the charge materials.

Since both the furnace lining and the molten alloy in acidic furnaces have acidic characteristics, this can lead to accelerated erosion of the lining. For this reason, strict control of the chemical composition of the charge is essential [4]. Before starting the furnace, it is necessary to inspect its operational condition. After a single melting cycle, the furnace lining may already show signs of wear or damage.

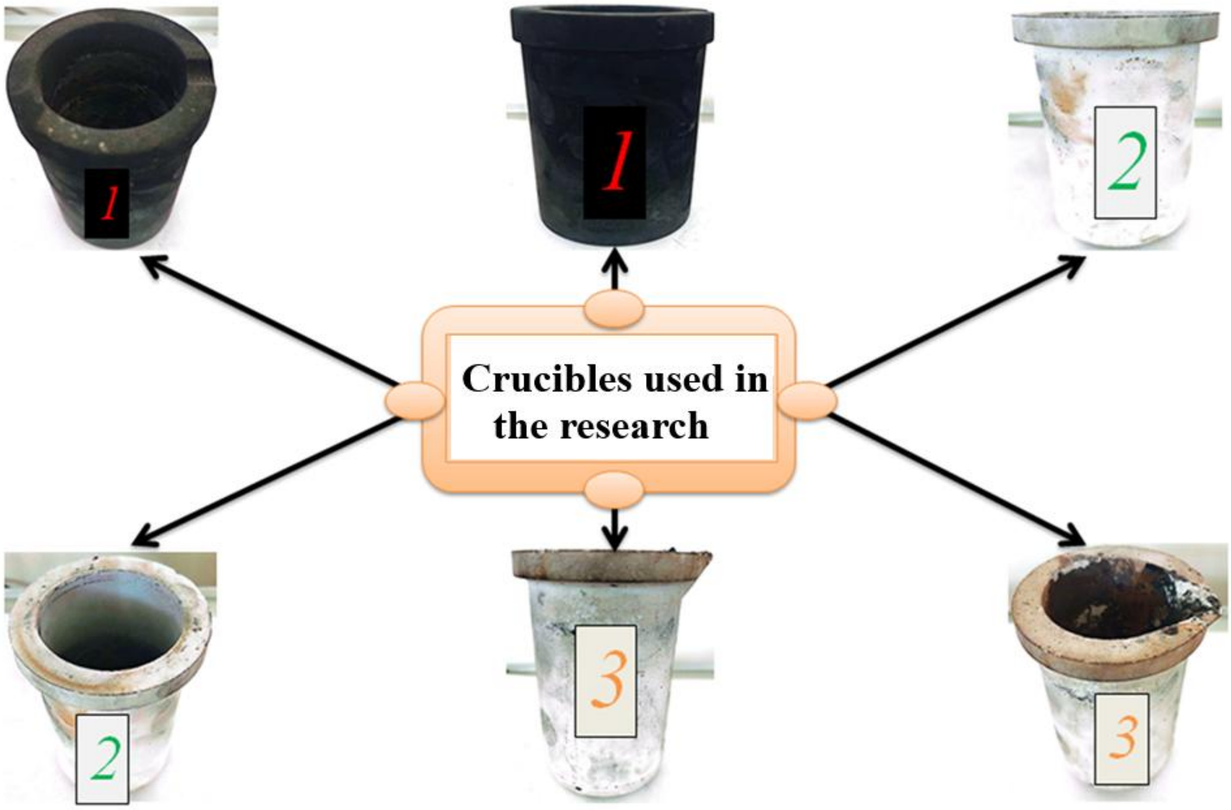

Figure 1. Crucibles used in the research. 1-Graphite (C), 2-Silicon dioxide (SiO_2), 3-Aluminum oxide (Al_2O_3)

First of all, before charging the furnace with raw materials, the condition of the induction furnace crucible was inspected. The main reason for this is that if any residual metal or slag from previous melting operations remains adhered to the crucible, it can adversely affect the chemical composition and quality of the alloy to be melted [5-8]. In addition, the crucible has a limited-service life; a SiO_2-based crucible can typically be used for up to ten melting cycles. Therefore, it is recommended to check for cracks or thinning of the crucible walls.

The chemical composition of the used crucible consists of 92÷95% silicon dioxide (SiO_2), with 3÷5% impurities, including CaO and small amounts of Al_2O_3, Fe_2O_3 (iron (III) oxide) [9], and TiO_2 (titanium dioxide). The melting temperature of the crucible is approximately 1700 °C, which ensures its stability during the melting of steel alloys, including during alloying and flux treatment processes when temperature increases occur. The crucible was selected to withstand such thermal variations without any negative effects.

After verifying the reliability of the crucible, primary and secondary charge materials were prepared. Since an induction furnace was used, medium-sized charge materials (45÷55 mm) were first loaded into the crucible. This is because the induction furnace melts materials through electromagnetic induction, causing the initially loaded charge to heat up first and then gradually melt.

During the operation of the induction furnace, the slag formed from the molten metal contributed to increasing the erosion resistance of the furnace lining. After the charge was melted, pre-prepared ferroalloys FeCr100A and FeTi35 were introduced into the furnace through the slag layer on the surface of the molten metal. This not only ensured the production of high-quality steel alloy but also led to the formation of TiO_2 and Cr_2O_3 on the furnace lining [10]. As a result, a protective oxide layer formed on the surface of the refractory material, enhancing the erosion resistance of the lining.

RESULT

The primary cause of furnace lining wear is the acidity of the steel, as well as its high temperature and the pressure conditions, all of which accelerate the erosion process. As mentioned above, the wear resistance of the furnace lining was improved by restoring the damaged inner lining through the formation of Cr_2O_3 and TiO_2, which create a protective layer and enhance resistance to erosion.

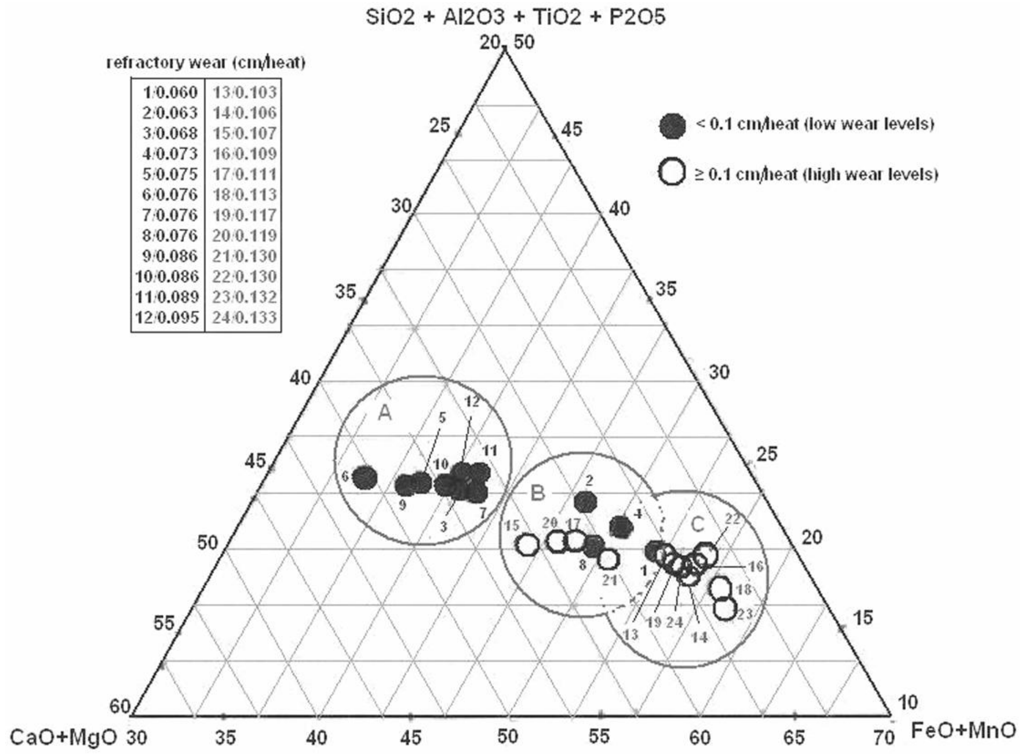

Figure 2. Diagram of the exact wear rate for (SiO_2 + Al_2O_3 + TiO_2 + P_2O_5)

During the inspection of the electric arc furnace, the effects of slag components (CaO, MgO, FeO, SiO_2, Al_2O_3) and metal phase elements (C, Mn) on the service life of the furnace lining were analyzed graphically. For better visualization of the data, as shown in Figure 2, the diagram illustrates the relationship between basic and acidic oxides and their interactions.

Conclusion

Based on the conducted research, it can be concluded that the service life and performance of furnace linings in electric and induction furnaces are strongly influenced by the chemical nature of the refractory materials, slag composition, and operating temperature conditions. Acidic linings, particularly those based on SiO_2, are more susceptible to accelerated wear due to the combined effects of high temperature, pressure, and the acidic nature of the molten steel.

The study demonstrated that proper control of charge composition and slag chemistry is essential for minimizing lining degradation. In particular, the introduction of ferroalloys such as FeCr100A and FeTi35 plays a significant role not only in improving the quality of the molten steel but also in enhancing the durability of the lining. This is achieved through the formation of protective oxide layers (Cr_2O_3 and TiO_2) on the refractory surface, which act as barriers against chemical and thermal erosion.

Furthermore, the reuse of spent refractory materials and slag for lining restoration presents an effective and resource-efficient approach.

The optimization of ramming regimes and the standardization of slag composition contribute to extending the operational life of furnace linings and improving overall process efficiency.

In general, the results confirm that a – combining material selection, process control, and protective oxide formation – can significantly reduce lining wear, increase furnace reliability, and enhance the economic efficiency of metallurgical operations.

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