WEAR OF HIGH-FIRED PERICLASE–SPINEL REFRactories IN THE ROOF OF A DOUBLE-BATH STEEL-MELTING FURNACE

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For metallurgical furnaces operating with oxygen a technology has been developed for making high quality periclase-spinel refractories [1]. It specifies the use of Satkinsk magnesite grade-1 and beneficiated Kempirsaiisk chromites of increased purity; in addition the products need to be fired at high temperatures (1750°C).

The periclase-spinel products obtained with this technique contain 94-95% periclase with spinel and 5-6% silicates. The structure of the product contains typically a uniform crystallization of secondary spinel ensuring a direct bond between the grains of periclase and chrome–spinel. The secondary spinel formed in such refractories develop a melting point of 2150°C. Depending on the number of direct bonds between the highly refractory minerals we obtain refractories approximating products with a direct bond.

In the present article we describe the results of a study of the wear processes in experimental periclase–spinel refractories in the roof of a double-bath steel-melting furnace at the Magnitogorsk Metallurgical Combine operating with oxygen blow in the bath. The experimental refractories were placed in the main roof of the furnace over the left bath (18 rings). During service in the section made from experimental refractories, scaling and erosion were not observed. During cold repairs the furnace was stopped after producing 609 heats. The wear in experimental refractories on average was 2.32 mm per day instead of 3.05 mm per day for ordinary refractories; that is, the life of the material studied increased by 30%.

In the experimental refractories we observed three zones: working (thickness 10–15 mm), transition (25–30 mm), and least changed (280–300 mm). The working zone was black with a metallic shine and strong fusion. We could clearly discern channels and cavities indicating the erosive nature of the wear. The transition zone was dark brown, dense, and slightly vitrified. The least-changed zone in external appearance was no different from the preservice products. The structure of the least-change zone was similar to that of the unused refractory. In this zone the aggregates of periclase grains were thoroughly cemented by a bond made from modified chrome–spinel of angular form and rounded grains of periclase. Between the periclase and the chrome–spinel there was a predominant direct bond, and in the aggregates of periclase grains the role of direct bond was played by the secondary spinel (Fig. 1).

The transition zone can be microscopically divided into two subzones distinguished in structure and the form of the crystals of the separate minerals: subzone saturated with silicates and recrystallization subzone. The first subzone (Fig. 2) differs from the least-change zone by the increased concentration of silicates which fill the micropores of the bond and the peripheral parts of the aggregate, and also by the corroded darkening of the grains of the changed chrome–spinel. The grains of periclase in this subzone in form are similar to the grains of the least-change zone.

In the recrystallization zone there is some changed chrome–spinel and large crystals of secondary spinel (Fig. 3). The periclase in the main acquired a polygonal form strongly reminiscent of secondary spinel. The grain size of the periclase is somewhat increased and becomes equal to 40–140 μ instead of 20–120 μ in the least-change zone. The basic advantage of the structure in the transition zone of the experimental refractory over the structure of the ordinary products is the slight growth of the crystals of periclase and the direct bond between them.

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Fig. 1. Microstructure of aggregates of periclase grain in the least-change zone of experimental periclase—spinel refractories: 1) periclase with inclusions of spinel; 2) secondary spinel; 3) silicates (×500). Reflected light.

Fig. 2. Microstructure of the bond in the subzone saturated with silicates (transition zone) of the experimental refractories: 1) periclase with inclusions of spinel; 2) changed chrome—spinel; 3) silicates; 4) pores (×500). Reflected light.

Fig. 3. Microstructure of bond in the subzone of the recrystallization (transition zone) in experimental refractories: 1) periclase saturated with spinel; 2) secondary spinel; 3) silicates (×500). Reflected light.

Examination of the working zone under the microscope shows two separate zones: periclase—magnesioferrite and magnetite. The magnetite subzone is seen microscopically as a slag button 5–8 mm thick. The periclase—magnesioferrite subzone (Fig. 4) consists of a solid solution of periclase and iron spinel. The grains of solid solution (measuring up to 120 μ) are isometric and similar to grains of the recrystallized periclase. In this subzone there is absolutely no changed chrome—spinel and we observed marked degeneration of the periclase grains. The magnetite zone (Fig. 5) consists mainly of grains of iron spinel measuring from 50 to 160 μ and silicates. This subzone contains almost no periclase.

The chemical composition of the experimental refractory zones (Table 1) indicate its fundamental degeneration. On the basis of equilibrium phase compositions (Table 2) we can conclude that in the least-change zone the basic phases are periclase (62.2%) and spinel of the composition Mg(Cr, Fe, Al)2O4 with a predominance of magnochromite molecules, and in the working zone magnesiowustite and magnesioferrite. In the magnetite subzone there is absolutely no free periclase. The nature of this change in the refractory can be properly traced from cationic composition formulas (Table 3) from which we see that in the transition zone there is a marked contribution from the magnesium cations, calcium, and silicon; and in the working zone the cations of magnesium and chromium are almost completely replaced by cations of iron and manganese. As a result of microscopic studies of the experimental and standard refractories after service in the roof of the double-bath steel-melting furnace we establish the following differences in the changes in composition and structure of the zones.

In the experimental refractory the periclase varies in the composition and morphology of the grains, commencing with the transition zone. In the silicate saturated subzone we observe a slight growth in the grains (on average from 80–120 μ). Between the periclase grains there is a predominant bond with the films of secondary spinel.

In the similar zone of ordinary periclase—spinel refractory the periclase grains are sharply increased in size (on average from 70–250 μ); as a rule they are divided by silicate interlayers. Furthermore in ordinary refractories we note the formation of cracks due to secondary sintering of the textual elements and recrystallization of the periclase grains. In the working zone the periclase is almost completely converted into ferrite spinel. This spinel in the experimental refractory is formed on the surface of the periclase aggregates, and in the ordinary refractory in which there is no direct bond over the entire volume, which accelerates the wear of the product. The composition and properties of the chrome—spinel vary in the recrystallization subzone, in which it reacts with the iron oxides entering from the working zone. As a result the composition of the chrome—spinel changes from magnochromite to magnoferrichromite. The equations of these spinels take the form: