for 220 and 197 heats, respectively, and were stopped for repairs according to the graph. The residual thickness of the blocks was 70-120 mm, the chromite—periclase refractory 120-130 mm. Furnace No. 9 after 215 heats was also stopped for repairs according to schedule. The brick and concrete linings were demolished by exploding them into the slaggers. The metal girder was burnt off which indicated the low residual thickness of the brick and concrete linings. The wear of both linings was identical.

On the basis of the positive data obtained during the use of the refractory blocks produced locally, we conducted industrial trials with these articles. The tests made use of chromite—periclase blocks KhMBB-3 as specified by ChMTU 14-8-101-74 made by the Panteleimonovsk refractories factory. The weight of the blocks was 0.32 tons, i.e., similar to that earlier tested. Studies showed that the resistances of the locally produced blocks and those made by the Panteleimonovsk factory on the average are the same.

The installation of the blocks at KMK is done according to the following scheme: the blocks are delivered to the working area of the open-hearth furnace No. 1 on open railroad platforms. Using autodumpcars with a lifting capacity of 5 tons and a fast jib, on the hook of which is secured a clamp, the platform is unloaded. The jib is secured on the forks of the dumpcar. To unload 60 tons of blocks, two operatives spend an average of 10 h on this operation. Then the blocks are placed on the base 10-12 items each with the broken joint system. The fast jib removes the bases with the blocks from the fork lift truck and transports them to the warehouse.

During the repair time on the open-hearth furnace, in order to place the blocks in the front walls of the vertical channels, monorails are placed from the H-beam which secures it to the front and rear supports of the open-hearth head. An electric telfer is established onto the monorail with a loading capacity of 0.5 ton. The clamp is suspended on the hook of the electric telfer raising the blocks and supplying them to the placement site into the front wall.

CONCLUSIONS

The degrees of wear of fired chromite—periclase refractory produced locally, and of chromite—periclase concrete blocks in the front walls of 400-ton open-hearth furnaces of the Combine are practically identical. It is necessary to develop special devices to obtain wider use of these block placements during the repairs of open-hearth furnaces.

REACTION OF SLAG COATING ON THE METAL SURFACE IN A CRYSTALLIZER WITH SUBMERGED NOZZLES

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UDC 666.762.11+666.762.81].017:620.178.16

Immersed nozzles used for continuous casting of steel are made from quartz ceramics with different alumina—graphite compositions. Using alumina—graphite nozzles causes wear to occur in the crystallizer at the level of contact with the slag melt of the coating which protects the metal surface. This is one of the causes of the ineffectiveness of using nozzles made from alumina or chamotte with graphite instead of the costly and scarce quartz nozzles.

This article presents the results of an investigation of the reaction of slag melt and immersed nozzle, and the effect of the slag and refractory composition on the wear of the latter.

The slag resistance of the refractory was determined by the known method on equipment described in [1], using fixed specimens, and specimens rotating at a frequency of 25-400 rpm. Tests were made at 1450°C corresponding to the temperature in the slag—refractory contact zone. The experimental slag was

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Lipetsk Polytechnical Institute. I. P. Bardin Central Scientific-Research Institute of Ferrous Metals. Novolipetsk Metallurgical Factory. Translated from Ogneupory, No. 9, pp. 35-38, September, 1981.

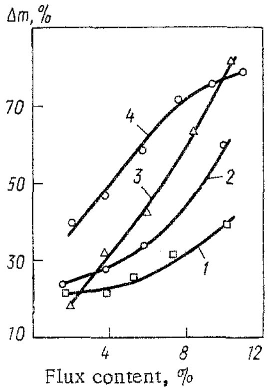

Fig. 1

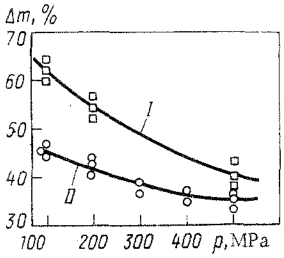

Fig. 2

Fig. 1. Effect of type and amount of fluxes on the slag resistance of alumina–graphite specimens (stationary schedule): 1) calcium chloride ($CaCl_2$); 2) fluorspar (CaF_2); 3) cryolite (Na_3AlF_6); 4) sodium nitrate ($NaNO_3$).

Fig. 2. Effect of composition and fabrication pressure p for refractory specimens on their slag resistance (I, II – compositions).

prepared from chemically pure materials. With regard to components, the synthetic slag was identical to the actual slag formed in the crystallizer on the metal surface in industrial conditions: 42%* CaO, 30.9% SiO_2, 18.4% Al_2O_3, 2.5% MgO, 2.1% FeO, 4.2% MnO.

Assuming that the destructive action of the slag on the refractory is mainly determined by the composition and amount of fluxes, we studied the effect of fluorspar, cryolite, sodium nitrate, and calcium chloride on specimen wear. The content of fluxes in the test slags was increased from 2 to 12%. The specimens in the form of cylinders 5 mm high and 15-mm diameter were prepared from an immersion alumina–graphite nozzle with a composition (parts by weight): Al_2O_3 65.0%, SiO_2 15.3%, C 15.6%, and Fe_2O_3 1.7%. The open porosity of the specimens was 13.7%.

The contact time of slag and refractory was 30 min. With such a soaking the slag wear was thoroughly fixed. The degree of wear of the refractory specimen was determined from the equation

$$\Delta m = \frac{m_{\text{init}} - m_{\text{fin}}}{m_{\text{init}}} \cdot 100,$$

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*Here and subsequently parts by weight shown.

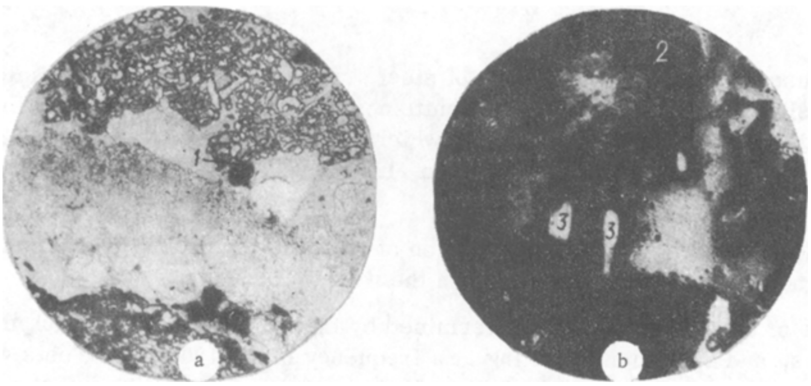

Fig. 3. Microstructure of refractory before (a) and after (b) reaction with slag: 1) graphite; 2) slag; 3) buttons of reduced metal, × 200. Reflected light.

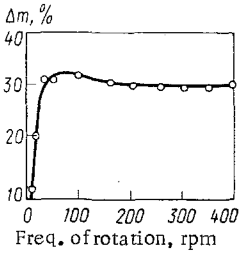

Fig. 4. Effect of frequency of rotation of specimen on the slag resistance of the refractory.

where Δm is the specimen wear, %, m_{init}, weight of the specimen before the test, g; m_{fin}, weight of the specimen after the test, g.

The weighing accuracy was ±0.001 g.

The results for a stationary schedule for various flux additions are shown in Fig. 1. In terms of the rise in corrosive action, the fluxes take the following order: $CaCl_2$, CaF_2, Na_3AlF_6, $NaNO_3$. In this case the destructive action of the fluorspar and calcium chloride is reinforced when they are present in the slag in amounts of more than 6%.

Calcium chloride is the best flux from the point of reducing the corrosive action of slag on the refractory. But its use in slag-forming mixtures is hindered because of its hygroscopicity [2]. It is favorable to use calcium chloride in fluxed slag-forming mixes.

Figure 1 shows that to reduce the slag wear of immersed alumina—graphite nozzles it is necessary to introduce into the compositions of protective mixtures, cryolite, sodium nitrate, or fluorspar, in amounts which conserve the physical properties of the slag layer at a certain level. Earlier work [3] showed that the optimum physical properties of the slag layer are preserved with a slag content of fluorine in the limits 6-8%, and for compounds of the type R_2O 2-6%. These conclusions agree well with the results obtained in our study.

The slag resistance of the refractories was studied on specimens of two compositions: No. I — 68.9% Al_2O_3, 19% SiO_2, 10.9% C, 1.3% Fe_2O_3 and composition II — 60.4% Al_2O_3, 26.0% SiO_2, 11.7% C, 2.5% Fe_2O_3. The specimens were pressed at pressures from 100 to 500 MPa. Liquid slag was obtained by melting slag-forming mixtures used in industrial conditions. The chemical composition of the slag was: 40.3% CaO, 39.6% SiO_2, 7.8% Al_2O_3, 2.1% Fe_{tot}, 3.1% MnO, 6.9% F, 0.2% C.

It follows from data (Fig. 2) obtained that composition II has the higher slag resistance. With pressure rise on the specimens (and hence the reduction in porosity) the wear sharply slows down as a result of the reduction in the true surface of contact between slag and refractory. In this case the effect of the chemical composition of refractory on slag resistance is less marked.

Petrographic study of specimens in contact with slag enabled us to identify the mechanism of corrosion of refractory over slag belts. The structure of the alumina—graphite refractory before and after reaction with the slag is shown in Fig. 3.

In the original specimen the graphite is arranged randomly in the form of platelets. The bonding mass contains light sections of recrystallized clay substance with fine crystals of mullite and chamotte grains. After contact with the slag we note its penetration into the pores of the refractory. With an increase in the duration of contact the amount of slag increases, and in places of interaction between slag and refractory there are sections with a metallic phase. Reduction of the metal from MnO, FeO is effected by the carbon in the refractory, and then the developing pores are filled with molten slag. Subsequently, mainly solution of the refractory in the slag melt occurs. Consequently, the high liquid mobility of the slag and the presence in the contact zone of strong oxidizing agents (FeO, MnO) accelerate the wear of immersion nozzles.

Solution of the refractory in the slag occurs in the diffusion region as indicated by the increase in the rate of solution during conversion from a stationary specimen to a rotating one (Fig. 4). A particularly marked wear increase is seen with a rise in the frequency of rotation of the specimen to 25 rpm (wear about 35%). Further increase in the rpm does not have a marked effect on its solution. Apparently, when the specimen rotates at 25 rpm a maximum solubility of refractory in the slag is attained, and a subsequent increase in rpm does not provide a marked increase in the diffusion flow of slag into the refractory.

CONCLUSIONS

The wear of alumina—graphite immersion nozzles is greatly affected by the amount and type of fluxes in the composition of the slag-forming protective mixtures. In terms of the increasing corrosion capacity, fluxes are arranged as follows: calcium chloride, fluorspar, cryolite, sodium nitrate. With a content of more than 6-8% fluxes, the degree of wear sharply increases.

With a rise in the fabrication pressure and hence a reduction in the porosity, the resistance of the refractories increases.

In the contact zone for slag and refractory, penetration of slag into the refractory occurs, as well as oxidation of the carbon by active oxidizing agents (FeO, MnO), and the formation of fusible eutectics. The solution rate of refractory in slag melt increases with a change from a fixed specimen to a rotating one.

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DESTRUCTION MECHANISM OF BASIC REFRACTORIES IN FLAME FURNACE ROOFS

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UDC 666.762.3: 66.043.1.017]:620.178.16

Previously a study was made of the mechanism of destruction in aluminosilicate refractories as a function of the concentration of main oxide (Al_2O_3) [1], which clarified the chief properties determining the suitability of using them in roofs of flame kilns and furnaces. However, from comparative tests of aluminosilicate and basic refractories it was found that the latter have advantages [2] which indicates that they might be prospective materials for use in such sites.

To clarify the requirements of experimental work connected with improving the quality of basic refractories used for lining flame furnaces, the authors studied the destruction mechanism of magnesia—spinel products after they had been tested in the roof of a flame furnace.

The annular structure of the roof was made from MKhS and PShS articles, and included 22 rows from the water-cooled ring up to the seal of a plasmatron. Tests were made in conditions of a neutral atmosphere with a low concentration of smelter dust in the subroof region of the furnace. The most typical temperature of the working surface in the lining is in the center and periphery of the roof which was maintained during the entire campaign and is shown in Table 1.

Observations of the state of the working surface of the roof lining during operations showed that the main type of wear is cracking of the articles and their subsequent scaling in pieces measuring 25-50 mm. The external appearance of articles taken from the center and periphery of the roof after 61 heats is shown in Fig. 1.

TABLE 1. Temperature Schedule of the Working Surface of the Roof Lining from Experimental Refractories in a Flame Furnace during Melting

Lining section	Temp. at end of melting, °C	Temp. gradient across lining thickness (0-50 mm) in period of restoring thermal equilibrium	Temp. of lining during movement of the bath being charged, °C
Near plasmatron	1830—1850	9,4—10,5	850—750
At periphery of roof	1740—1760	8,5—9,3	700—600

Eastern Institute of Refractories. Translated from Ogneupory, No. 9, pp. 38-43, September, 1981.