HIGH-ALUMINA LOW-FIRED PRODUCTS BASED ON KYANITE – SILLIMANITE CONCENTRATE

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In order to increase the resistance of aluminosilicate refractories, corundum or processed alumina [1-4] is added to the most vulnerable and finely milled bonding part of the composition. An addition of alumina leads to the formation of mullite bond at temperature above 1300°C, causes the bodies to be "shrink-free", and makes it possible to prepare low-fired products from such bodies which possess enhanced strength at high temperatures [1, 2].

The Ukrainian Institute of Refractories, in developing a production technology for high-alumina low-fired shrink-free bodies, added to the composition of the finely milled constituents natural high-alumina raw materials in the form of kyanite–sillimanite concentrate from the Verkhnedneprov Combine. The concentrate is a powder consisting mainly of grains measuring 0.2-0.9 mm. The mineral composition of the concentrate is 50-58% sillimanite, 32-40% kyanite, 2-6% zircon, and 2-6% quartz. At temperatures above 1200°C the kyanite is converted into mullite with an appreciable increase in volume which causes the products to become shrink-free during heating, and therefore it is not necessary to fire them at high temperatures.

In developing the production technology for such refractories use was made of research results connected with ramming bodies using kyanite–sillimanite concentrate. The properties of the starting materials

TABLE 1. Properties of Starting Materials

Material	Chemical composition, %									Refractoriness, °C
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	ZrO_2	R_2O	L.o.i.*	
Chamotte made from Novoselitsk kaolin KNO†	52,98	44,12	0,9	1,34	0,24	0,17	—	0,22	—	1720
Kyanite–sillimanite concentrate from the Verkhnedneprov Combine	36,92	58,36	0,46	0,76	—	—	2,9	0,17	0,32	1830
Fused corundum from the Tikhvinsk Alumina Factory	0,29	98,76	0,39	0,02	0,08	0,01	—	0,45	—	2050
Polozhe kaolin PLKO	48,68	35,27	0,99	0,86	0,43	0,05	—	0,52	12,96	1770

* L. o. i. = Loss on ignition, %

† Water absorption of the chamotte 5.5%.

TABLE 2. Compositions of Bodies, %

Body number	Chamotte made from Novoselitsk kaolin (3-0.5 mm)	Ground mixture			Addition on 100%	
		kyanite–sillimanite concentrate*	Polozhe kaolin	electric-fused corundum	sulfite lye on dry substance	orthophosphoric acid expressed as H_3PO_4
37	55	35	10	-	1	-
38	55	27	8	10	1	-
60	55†	35	10	-	-	3.5

* Content of fractions <0.09 mm, 90%.

† Including 6% fractions 5-3 mm.

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TABLE 3. Properties of Products Fired at 1200°C

Body number	Chemical composition, %									Refractoriness, °C	Refractoriness under load, 2kg /cm²			Creep at 1300°C under a load of 2 kg/cm² in 8 h, %
	loss on ignition, %	SiO_2	Al_2O_3	Fe_2O_3	ZrO_2	TiO_2	CaO	MgO	R_2O		start of softening	4% sag	40% sag	
37	0,48	47,36	49,57	1,19	0,65	0,14	Trace	0,15	0,20	1730	1420	1520	1600	1,6
38	0,40	42,28	54,07	1,19	0,80	0,14	"	0,36	0,51	1750	1440	1540	1670	1,9
60	Not determined										1420	1480	1540	1,7

are given in Table 1, and the composition of the bodies from which ladle brick was made are given in Table 2.

The advantage of making ladle brick from bodies containing an addition of orthophosphoric acid should be confirmed by service tests and by studies of the quality of the cast metal.

Experimental bodies were prepared in mixer runnermills. First the coarse-grain chamotte was loaded into the runnermill, and moistened with slip, which consists of 2% finely milled mixture, 4% water, and 2% sulfite lye with a density of 1.26 g/cm³, or 7-8% orthophosphoric acid with a density of 1.35 g/cm³ (body No. 60), followed by blending for 1-2 min, and then the addition of ground mixture prepared in a ballmill; the whole was blended for a further 10 min. The resulting body was screened through a sieve with 5 mm mesh. The moisture content of the bodies was 3.9-4.5%, and the grain-size distribution: 17% fractions 3-2 mm, 22.32% 2-0.5 mm, 9-13% 0.5-0.09 mm, and 44-48% <0.09 mm.

Bodies Nos. 37 and 38 were used to make ladle brick of trapezoidal shape, grade KM-8, with dimensions 214 × 176 × 120 × 82 mm on a fraction press using 8-10 pressings. Body No. 6 was used to make products measuring 300 × 150 × 175 mm by ramming with a pneumatic tamper at an air pressure of 5.5-6 atm. The products after drying were fired in a periodic kiln at 1200°C with a soak of 10 h. Moderate quantities of products were fired also at other temperatures for investigation.

The properties of the products are given in Tables 3 and 4. After repeated firing at 1450°C the products were fired at 1200°C and had scarcely any residual volume changes: the after-shrinkage of the brick made from body No. 37 was 0.1-0.3%, and from body No. 38 the expansion was 0.3%.

TABLE 4. Properties of Products Fired at Different Temperatures

Body number	Firing temperature, °C	Apparent porosity, %	Shrinkage (−), expansion (+), %	Compressive strength, kg /cm²
37	1000	19,5	0	260
38		19,5	+0,2	335
37	1200	18,2	+0,7	410
38		18,2	+0,8	500
60		13,5	+0,3	950
37	1300	18,5	+0,4	330
38		19,3	+0,7	420
60		13,4	+0,1	700
37	1400	21,4	+0,8	360
38		19,1	+0,9	490
37	1500	12,4	−1,2	690
38		15,9	−0,7	930
60		13,9	+1,3	640

The products fired at moderate temperatures (1000 and 1200°C) had a high strength, and a moderate porosity. Very good strength properties and a high density were possessed by products made from bodies containing orthophosphoric acid. After firing at higher temperatures (1300 and 1400°C) the properties of the goods hardly altered. This confirms that it is possible to fire refractories made by the newly developed technology at moderate temperatures. The deformation temperature of the products with a sulfite lye bond was higher than that of products containing orthophosphoric acid. After firing at 1500°C the product with the sulfite lye, as a result of sintering, had a moderate shrinkage, a high density, and a high strength.

The ladle brick of the experimental batch made from bodies Nos. 37 and 38 fired at 1200°C were tested in two steel casting ladle of capacity 9 ton, for casting high-manganese electric steel LG-13 of the following composition: 1.1-1.5% C; 11-15% Mn; 0.6-1.0% Si; 0.12% P. Composition of slag: 35.32% SiO_2; 9.26% Al_2O_3; 0.49% Fe_2O_3; 24.65% CaO; 16.86% MgO; 11.52% MnO.

The experimental ladle brick was compared with KM-3 ladle brick produced by the Chasov Yar Refractories Combine. The chemical composition of this brick was 60.6% SiO_2, 35.51% Al_2O_3, and 1.2% Fe_2O_3; the refractoriness 1740°C; the apparent porosity 17.8%, and the compressive strength 360 kg/cm^2. In lining the ladle the industrial firebrick KM-3 was used at the working side toward the bottom to lay extra material up to a height of two rows from the base of the ladle bottom. The total thickness of the working lining in the lower part of the ladle was 120 mm. The bricks were laid with chromite – clay mortar, consisting of 70% chromite ore and 30% clay. The lining of the ladle was dried with gas burners in a period of 2-3 h.

The service conditions of the ladle linings were: dwell time of the metal in the ladle from the start of discharge from the furnace to completion of the cast 20-25 min; time of dwell of slag in the ladle after completion of the cast 4-12 min; time between the castings for one and the same lining 1-3 h. The life of the linings in the ladle made from fireclay ladle brick during the test was 9-10 heats. The duration of the campaign for the ladles was normally determined by the wear of the lining in the lower two courses approximately at a height of 500 mm from the bottom. The wear in these courses was on average 7.4-11.8 mm per heat.

The experimental brick was tested in the lower, most vulnerable part of the ladle lining. During the first tests with the experimental brick using body No. 37, the bottom and 8 lower courses of the lining to a height of about 700 mm were laid. The structure was built on mortar consisting of 30% chamotte made from Novoselitsk kaolin, 63% kyanite – sillimanite concentrate, and 7% Polozhe kaolin. The ninth course of the lining was built from firebrick KM-3, and the upper tenth course with slabs.

The experimental lining of the ladle after drying with gas burners in a period of 2.5 h was free of defects. The ladle lining lasted 20 castings. After service it was in an excellent state, and showed no wear at the joints. The average wear of the experimental brick in the 1-8th courses of the lining was 1.75-3.90 mm per cast. The firebrick nest structure and part of the experimental brick at the bottom directly in contact with the nest showed appreciable wear. This was the cause of terminating the ladle campaign.

Petrographic studies of the brick after service showed that at its working side (in the fine grains) the kyanite had completely changed into mullite, but in the coarse grains the kyanite had preserved its original state only in the central part.

During repeat testing the experimental brick made from body No. 38 was used to lay the first four rows from the bottom of the ladle and part of the base. The structure was made with the same mortar as in the first test. The remaining parts of the lining in the walls and part of the base were made from firebrick KM-3.

The lining of the ladle lasted 17 castings; after termination of the campaign it was in excellent condition, and showed no signs of wear at the joints. The bottom in the central section was worn, and some of the joints had expanded. This was the cause of replacing the lining. The average wear of the brick in the lower four rows of the structure was 2.7-4.7 mm per casting.

The duration of the campaign with the experimental linings was about double, and the wear 2.5 times less than that of the firebrick.

The results confirm that it is possible to use the high resistance of experimental low-fired brick with an addition of kyanite – sillimanite concentrate for lining steel casting ladles, when handling high-manganese steel.

CONCLUSIONS

A technology was developed for making high-alumina low-fired products using kyanite – sillimanite concentrate with a sulfite-lye or orthophosphoric acid bond.

The possibility was established of using low-fired brick at service temperatures of up to 1500°C. The tests of these high-alumina products in steel casting ladles of different capacities and in industrial kilns with different service conditions enabled us to establish the most effective locations of their use.

LITERATURE CITED

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