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FORSTERITE-CONTAINING PARTS FOR AIR HEATERS OF BLAST FURNACES

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Results of a detailed investigation of the properties of forsterite-containing refractory parts as applied to the service conditions of air-heater checkerwork in blast furnaces are presented. An experimental industrial batch of forsterite-chromite hexagonal checkerwork parts was prepared. The results of their service in an air heater are described.

In the last 25 years dinas parts have been used preferentially in high-temperature zones, including the checkerwork of newly constructed, reconstructed, and repaired air heaters in blast furnaces. At the beginning their stemmed from the need to increase the total heat power of air heaters and made it possible to raise the blast temperature to 1200 – 1300°C (in the future it may be possible to increase the blast temperature to 1400°C at a near-roof temperature of 1550°C, i.e., up to the recommended maximum temperature of dinas in air heaters). Dinas parts are produced by the technology developed by the Ukrainian Research Institute of Refractories for the service conditions of linings of air heaters [1, 2]. The use of dinas in the lining of high-temperature zones has increased their stability substantially [3 – 5].

Further improvement in the thermal power of the checkerwork for existing sizes of air heaters is possible in principle using refractories having a high apparent density and high thermophysical parameters.

Abroad, periclase refractories with a reduced mass fraction of iron oxides have been tested successfully in the upper high-temperature zones of air heaters of blast furnaces. By using periclase refractories the mass of the checkerwork has been increased substantially [6].

The efficiency of using periclase refractories in air heater checkerwork as compared to that of other kinds of refractories stems from their high capacity for accumulating heat due to the high apparent density and thermophysical parameters. The high apparent density and specific heat capacity of periclase refractories lead to lower consumption of gas during heating of the checkerwork and an increase in the consumption of blast to 17% due to the high accumulating capacity and the high temperature of the blast at the same near-roof temperatures of the air heaters and for the same heating and blasting times.

The literature contains no data on the use of forsterite-containing refractories in the high-temperature zones of air heater checkerwork in blast furnaces.

In the present paper we present data on the properties and experience in the production and use of forsterite-containing parts in the checkerwork of air heaters.

We have conducted detailed investigations of the chemical composition and the ceramic, thermophysical, thermal-strength, and deformation characteristics of forsterite-containing parts necessary for operation in the high-temperature zones of air heater checkerwork in blast furnaces. In order to study the properties of parts produced by the NTMK (Nizhnii Tagil Metallurgical Combine) we chose representative specimens of forsterite and forsterite-chromite parts. The ceramic properties and the chemical composition of the investigated parts are presented in Table 1.

Our data show that the parameters of the properties of forsterite and forsterite-chromite parts produced by the NTMK correspond fully to the requirements of the current standard, and some of the properties, namely, the refractoriness and the temperature of the beginning of deformation under load (one of the main operating properties for checkerwork parts) are substantially higher than those in the standard. The apparent density of the parts (2.60 – 2.77 g/cm^3) exceeds the same parameter for dinas refractories (1.80 – 1.85 g/cm^3), i.e., the mass and hence the heat capacity of the same volume of the checkerwork lining will be correspondingly higher, which is very important for raising the accumulating capacity of the air heater checkerwork.

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TABLE 1. Characteristic of Forsterite and Forsterite – Chromite Parts

Parameters	Parts			
	forsterite		forsterite – chromite	
	standard	actual	standard	actual
Mass fraction, %				
MgO	≥ 54	58.45	≥ 46	53.15
SiO_2	22 – 33	30.34	16 – 30	21.40
Cr_2O_3	–	–	8 – 12	11.47
Refractoriness, °C	≥ 1750	1820	≥ 1750	1840
Temperature of the beginning of deformation under 0.2 MPa, °C	≥ 1590	1670	≥ 1550	1680
Ultimate compressive strength, MPa	≥ 30	39 – 43.3	25	34.5 – 46.1
Open porosity, %	≤ 24	20.5 – 21.3	≤ 25	20.1 – 20.4
Apparent density, g/cm^3	–	2.60 – 2.63	–	2.76 – 2.77

TABLE 2. Creep in Forsterite and Forsterite – Chromite Parts

Parts	Temperature, °C	Load, MPa	Deformation, %, in time, h	
			0 – 9	0 – 14
Forsterite	1100	0.3	0.007	–
	1200	0.2	0.018	–
	1300	0.15	0.014	0.020[*1]
	1400	0.1	0.040[*2]	–
Forsterite-chromite	1300	0.15	0.004	–
	1400	0.1	0.058	0.072

[*1] In 0 – 24 h the deformation is 0.024%.

[*2] Deformation in 0 – 18 h.

TABLE 3. Ultimate Compressive Strength of Heated Refractories

Parts	Ultimate compressive strength, MPa, at a temperature of, °C						
	20	1100	1200	1300	1400	1500	1550
Forsterite	63.6	49.3	37.7	36.0	34.5	32.4	17.1
Forsterite-chromite	59.6	51.6	49.0	48.0	26.0	23.5	16.4
Dinas	40.0	22.3	22.1	20.7	17.5	14.3	6.5

TABLE 4. Thermal Conductivity of Refractory Parts

Parts	Mean temperature, °C	Thermal conductivity, W/(m · K)
Forsterite	900	1.91
	1000	1.88
	1200	1.78
Forsterite-chromite	900	2.16
	1000	1.91
	1200	1.81
Dinas	900	1.25
	1000	1.31
	1200	1.65

The deformation characteristics of forsterite and forsterite-chromite parts are presented in Table 2. As can be seen from the table, the parts are characterized by considerable resistance to deformation (creep) at high temperatures and loads and can serve successfully in high-temperature zones of the checkerwork of air heaters of blast furnaces.

Tables 3 – 5 present data on the mechanical strength at different temperatures, the thermal conductivity, and the thermal expansion of forsterite, forsterite-chromite, and, for comparison, dinas parts.

Forsterite and forsterite-chromite parts have high thermal strength characteristics, and their ultimate compressive strength in the heated state at high temperatures is 1.5 – 2.5 times higher than that of dinas refractories. The thermal conductivity of the parts is also somewhat higher than that of dinas. The thermal expansion at temperatures above 1300°C is higher in forsterite and forsterite-chromite parts. Therefore, when they are used in the checkerwork of air heaters with near-roof temperatures of 1350 – 1550°C this should be taken into account, and the gap between the wall lining and the checkerwork should be increased.

We also investigated the interaction of forsterite and forsterite-chromite parts with dinas and mullite-corundum refractories at 1400, 1300, 1200, and 1100°C under loads of 0.1, 0.15, 0.2, and 0.3 MPa, respectively. We established that under these conditions the refractories hardly interact, and therefore forsterite and forsterite-chromite parts can be laid on dinas and mullite – corundum parts at any height of the high-temperature zone of the air heater checkerwork. It is expedient to use forsterite-containing parts in the upper high-temperature zone of the air heater checkerwork to 25 – 30% of the overall height.

An experimental industrial batch of forsterite-chromite perforated hexagonal checkerwork parts has been prepared at the refractory production of the NTMK. The parts were produced by the existing technology for forsterite-chromite refractories.

The initial raw material was fired dunite of fractions 2 – 3 and 0 – 2 mm, finely milled periclase, and chromite of fraction 0.5 – 3 mm. The gluing additive was commercial lignosulfonate (LST) with a density of 1.21 g/cm^3. The fired dunite was prepared from dunites of the Solov'evgorskoe Deposit. Crushed dunite (in lumps at most 80 mm in size) was fired in a rotary kiln at 1550°C. The fired dunite met the following requirements: an open porosity of at most 15%, a mass fraction of MgO of at least 46%, an MgO/SiO_2 ratio of at least 1.2. After the first crushing of the fired dunite in a jaw crusher it was crushed again in a KID-1200 short-cone crusher and then sieved on a GIL-32 vibrating screen into 2 – 3 and 0 – 2 mm fractions. The magnesia component of the charge was periclase powder with an open porosity of at most 16%, a mass fraction of MgO of at least 90%, at most 2.5% CaO, and at most 4% SiO_2. Periclase was crushed in a tube mill to at least 90% 0.06 mm fraction. Chromium ore of grade DKh 2-1 was produced by the Donskoi Beneficiation Plant. After crushing in a jaw crusher the chromium ore was

TABLE 5. Thermal Expansion of Refractory Parts

Parts	Thermal expansion, %, at a temperature of, °C														
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
Forsterite	0.04	0.16	0.28	0.36	0.47	0.58	0.69	0.80	0.91	1.04	1.17	1.38	1.54	1.74	1.86
Forsterite – chromite	0.03	0.13	0.24	0.34	0.43	0.53	0.63	0.75	0.87	1.01	1.15	1.31	1.45	1.61	1.76
Dinas	0.13	0.49	0.86	1.03	1.14	1.22	1.26	1.32	1.34	1.35	1.35	1.35	1.35	1.36	1.38

subjected to further crushing in a KID-1200 crusher and sieved on a GIL-32 vibrating screen to the 0.5 – 3 mm fraction.

The charge for the refractory parts had the following chemical composition: 16.6% fired dunite of fraction 2 – 3 mm, 41.0% fired dunite of fraction 0 – 2 mm, 21.3% chromite of fraction 0.5 – 3 mm, 21.1% finely milled periclase. The components were proportioned using a weigher. The mixture was prepared in an M-115 mixer beginning with the two granular components (dunite and chromite), which were agitated in a dry state for 30 sec, then the LST solution was added with mixing of the components for 20 sec, and then the finely milled periclase was loaded with mixing for another 60 sec. The duration of the cycle of mixture preparation was about 2 min; the moisture content of the mixture was 2.6%. The mixture contained 3.6% fraction coarser than 3 mm and 60% fraction finer than 0.5 mm, of which 36.4% was finer than 0.06 mm.

Hexagonal checkerwork parts were shaped in an SM 1085A toggle press at a load of 60 A on the engine. The parts were dried in tunnel dryers at a temperature of the heating agent of 200°C. The heating agent was hot air from the cooling zone of the tunnel kiln.

Pressed and dried hexagonal parts were fired in a tunnel kiln by the standard regime for forsterite-chromite refractories in two upper rows of the charge on a furnace car. The actual firing regime was as follows: 16 car pushes per day, a firing temperature at positions Nos. 30 and 31 in the firing zone of 1570 – 1600°C.

No parts were rejected after firing. The parts had the following parameters: a refractoriness of 1790°C, a temperature of the beginning of deformation under 0.2 MPa of 1620°C, an open porosity of 20.9 – 22.7%, an ultimate compressive strength of 31 – 33 MPa.

The hexagonal forsterite-chromite parts were used in the upper rows of the checkerwork of air heater No. 7 of blast furnace No. 3 with a useful volume of 1513 m^3. With allowance for the high thermal expansion of the forsterite-chromite parts the gap between the checkerwork and the wall lining was made 50 mm.

The air heater operated with a near-roof temperature of 1300 – 1320°C. After the reconstruction the temperature of the hot blast in furnace No. 3 was 25 – 35°C higher than before, which reduced the consumption of coke per ton of molten cast iron and increased the daily output.

The increase in the hot blast temperature was attained as a result of some measures undertaken by the workers of the shop, including the use of hexagonal forsterite-chromite parts in the upper rows of the checkerwork.

The parts served about 7 years before the air heater was completely reconstructed. The cells of the checkerwork were clean, and the hydraulic regime of the operation of the air heater was stable.

CONCLUSIONS

Data on the properties and experience in the production and use of forsterite-containing refractory parts shows the expediency and efficiency of their use in the upper high-temperature zone of air heater checkerwork in blast furnaces.

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