PRODUCTION AND SERVICE OF HIGH-ALUMINA CERAMIC CASTABLES.  
1. RAMMING MIXTURES BASED ON MODIFIED BAUXITE HCBS

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The prospects of using bauxite-base HCBS in the production of high-quality ramming mixtures for lining blast furnace spouts are considered. A system of Chinese bauxite (filler) and bauxite HCBS (binder) is shown to give a ramming mixture with a porosity of 18–22% and σr of 120 MPa. The effect of some process factors on the properties of the new refractory material is considered. The life of the mixture in the main hearth spout is shown to be 70–90 thousand tons cast iron before the first repair at a consumption of 0.53–0.63 kg mixture per one ton cast iron. The processes that occur in the interaction between the material and blast furnace slags of various chemical compositions is considered. The characteristics of the developed mixture are compared with those of the standard ones.

Spouts in blast furnace production are traditionally lined with mixtures based on chamotte, clay, and coke [1]. The binder in such mixtures is coal-tar pitch. A hearth spout lined with such a mixture withstands casting of 8–12 thousand tons iron until it wears fully; therefore a considerable part of the expenses falls to the cast house. The expenses can be cut substantially by replacing the traditional spout mixtures by mixtures of a new generation, which makes it possible to increase the service life of the spouts, improve working conditions, and ensure ecological safety of production at the same time. The monolithic linings used for the purpose in world practice are based on high-alumina materials that provide longer service of the spouts. In such mixtures the binder is a ceramic organic substance [2].

In 1997–1998 the Dinur Company produced spout mixtures of grade “Piram” using the technology of Plibrico GmbH (Austria). Since a part of the raw material arrived from Austria, the cost of the mixture was quite high. After the crisis in August 1999 in Russia the production of such mixtures became economically inexpedient. For this reason, Dinur specialists have made an attempt to develop a mixture and process for lining blast furnace spouts with an available material that would possess high working properties and reduce harmful effects on the environment.

Initial materials and binding system. The binder was a HCBS obtained by wet milling of bauxite with an additive of highly dispersed quartz glass.

The HCBS was prepared from heat-treated Chinese bauxite (delivered from Shanksi Province) that contained 85% Al2O3, 7% SiO2, 3% TiO2 [3]. The bauxite was milled, screened, and subjected to magnetic separation. The milling bodies were made of uralite with an apparent density of 3.10–3.15 g/cm3. The effective density of the milling bodies in the final milling stage did not exceed 0.40 g/cm3. The total milling time was 16–19 h.

The charge placed into the mill was enriched with highly dispersed quartz glass in the form of the waste of centrifugally shaped quartz refractories [4]. The additive corrected substantially the grain composition of the HCBS with respect to the content of the colloidal component [4], the presence and the concentration of which is a decisive factor for providing the requisite rheological properties of the HCBS. The density of the ready suspension was 2.72 g/cm3, the volume concentration of the solid phase C1 was 0.70, and the moisture content was 12%. The plasticizing additive was clay of the Nizhne-Uvelskoe deposit of grade NU2 (30% Al2O3, 60% SiO2, 3.5% Fe2O3).

The grain compositions of the suspensions and the mixes are presented in Fig. 1. Comparing the integral curves of the
distribution of the solid-phase grains, we can see a substantial
difference in the dispersity and polydispersity of the
clays, the waste, and the modified bauxite suspensions.

The rheological properties of the suspension were stu-
died with the help of a Rheotest-2 rotation viscometer. The
initial suspensions were characterized by principally differ-
ent flow patterns (Fig. 2). The bauxite suspension had a well
manifested thixotropic-dilatant flow (the coefficient of
dilatancy at \( \dot{\gamma} = 10 - 100 \text{ sec}^{-1} \) was equal to 1.9), whereas
the waste had a virtually Newtonian flow pattern. The bauxi-
te suspension with the waste was characterized by a lower
dilatancy; the optimum amount of the additive was
10 - 15%. The viscosity of the suspensions decreased as in
mixed suspensions of mullite and waste [4].

The specimens for determining the properties of the
binder were shaped by slip casting into gypsum molds to ob-
tain beams 70 x 10 x 10 mm and cubes with an edge of
40 mm. After the formation of the structure the castings were
withdrawn from the molds, "dry cured" in air, and dried to a
constant mass at 110°C. Then they were heat treated at vari-
ous temperatures with a hold of 1 h. The dependence of the
strength and the porosity of the castings on the treatment
temperature is presented in Fig. 3. At a high temperature the
mechanical strength is somewhat diminished. This effect is
explainable by the polymorphic transformations of the quartz
glass into cristobalite and the corresponding volume
changes.

Ramming mixtures were prepared with a filler of the
mentioned bauxite and silicon carbide (with at most 92%
SiC). The integral curves of the grain distribution in the
mixes are presented in Fig. 1. The composition with HCBS
of heat treated bauxite (30 - 40% dry substance) and a
polyfractional filler (60 - 70%) was chosen as a base variant.
The grain composition of the filler is presented in Fig. 1.

Preparation of the mix under industrial conditions was
performed in a roll mixer with a volume of 1.5 m³. At first
the fillers were mixed in a dry state and then with clay addi-
tives and the HCBS. The prepared mix was placed into 1-ton
soft containers.

The composition of the mix was chosen so that the open
porosity \( P_{\text{op}} \) upon ramming of the mix was at least 20%.

The properties of the mixes were studied for beam speci-
mens 230 x 55 x 65 mm in size fabricated by the method of
pneumoraming. The ramming was performed using a labo-
atory Frolich + Klupfel compactor with an impact fre-
quency of 800 strikes per minute in three layers with loosen-
ing the surface of each layer to a depth of 5 - 7 mm.

The porosity and the strength of ceramic castables is af-
fected substantially by the mass fraction of the binder \( m_b \) in
the initial molding sand system (Fig. 4). When \( m_b \) is in-
creased from 15 to 35% the porosity decreases by a factor of
1.9. The respective values of \( \sigma_c \) of the heat treated specimens

\begin{figure}
\centering
\includegraphics[width=\textwidth]{fig1.png}
\caption{Integral curves describing the grain distribution of: 1) Nizh-
ne-Uvelskoe clay; 2) high-dispersity suspension of quartz glass
(waste); 3) modified bauxite HCBS; 4) mix; 5) filler.}
\end{figure}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{fig2.png}
\caption{Dependence of the effective viscosity \( \eta \) on the gradient of
the shear rate \( \dot{\gamma} \) for the bauxite HCBS (1), the modified bauxite
HCBS (2), and the waste (3).}
\end{figure}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{fig3.png}
\caption{Dependence of the ultimate compressive strength \( \sigma_c \) (1) and
the open porosity \( P_{\text{op}} \) (2) of castings of modified bauxite HCBS on
the heat treatment temperature \( t \).}
\end{figure}