REFRACTORY PROPERTIES OF SILICEOUS BODIES FOR RAMMING THE LININGS OF ACID ARC STEEL FURNACES

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In recent years several factories have started to use rammed linings for the walls of acid arc steel furnaces. Replacing the brick linings by rammed linings greatly increases their resistance (from several dozen to several thousand heats), appreciably improving the production organization in steel casting workshops, reducing the furnace downtime, reducing the labor content of repair work, releasing production space previously occupied with the storage of refractories, reducing handling work, and also reducing the consumption of silica brick (dinas).

However, rammed linings for walls in such steel furnaces have not yet been introduced into the majority of factories. One of the basic reasons for this is the essential fettling of the walls of the furnace with refractory body after each heat with this method of lining, which is due to the inadequate refractoriness of the bodies employed, and as a consequence the fusion of the lining in the wall. Hot fettling of the walls of furnaces is a manual operation which the steel melter carries out from platforms welded to the housing of the furnace, exposed to very high temperatures.

Wide introduction of the ramming method for lining walls may follow from the development of suitable compositions for siliceous bodies conferring a high resistance to the rammed lining, without hot fettling during every heat when the steel is being heated for casting at high tapping temperatures (1700-1730°C).

These bodies should have a high refractoriness (apparently not less than 1740°C) which is determined by their chemical composition [1, 2], and by the quantity, composition,and rate of formation of the melt at high temperatures [3, 4].

This article gives some results of a study into the effect of the chemical composition of siliceous bodies on the refractoriness, on the basis of which the Kharkov Elektrotyazhmash Factory put into production

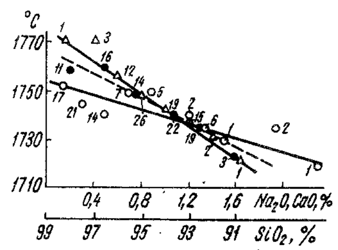


Fig. 1

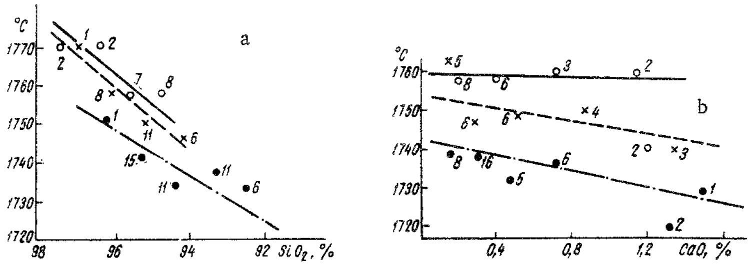
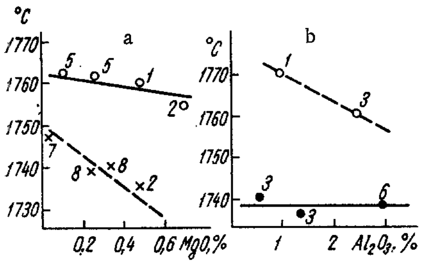


Fig. 2

Fig. 1. Relationship between the refractoriness of the body and the content of oxides in it. ○) CaO; ●) Na_2O; △) SiO_2, notation at the points indicates the number of samples investigated.

Fig. 2. Relationship between the refractoriness of the body and the content of SiO_2 (a) and CaO (b) with different contents of Na_2O: ○) up to 0.5%; ×) 0.51-1.0%; ●) 1.01-1.5%, notation near the points on the curves indicates the samples investigated.

Kharkov V. I. Lenin "Elektrotyazhmash" Factory. Dnepropetrov Metallurgical Institute. Translated from Ogneupory, No. 5, pp. 35-39, May, 1971.



Content of Al_2O_3 in the body, %

Fig. 3

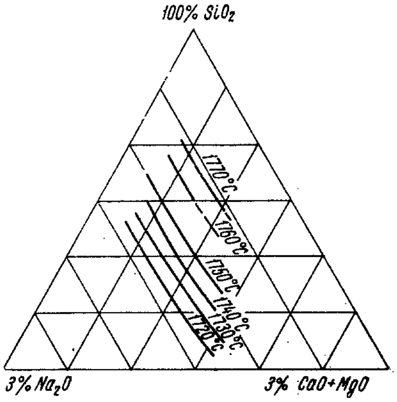


Fig. 4

Fig. 3. Relationship between the refractoriness of the body and the content of MgO (a) and Al_2O_3 (b) with different quantities of Na_2O: ○) up to 0.5%; ×, ●) 1.01-1.50%, notation near the points on the curves indicates the number of samples studied.

Fig. 4. Isotherms for high-siliceous section of the mixture $SiO_2-Na_2O-(CaO+MgO)$.

TABLE 1

Oxide	Value of coefficients in Eq. (1) A	B	Coefficient of correlation, r	Error in the coefficient of correlation m_r	$\sigma_r = \frac{r}{m_r}$
Na_2O	1768	—25	—0,725	±0,051	14,22
SiO_2	1163	+6,2	—0,560	±0,078	7,18
CaO	1751	—10	—0,324	±0,103	3,14

a ramming lining body for acid arc steel furnaces with a capacity of 5 and 0.5 ton without fettling the walls after every heat.

Previous experiments [5] showed that to ensure a high strength in the rammed lining and the necessary technical properties in the refractory body based on quartz sand, it should contain water glass, fireclay, and caustic soda. The need for adding these constituents requires careful study of the refractory body in conditions involving the combined action of oxides incorporated by additives, since the composition of the bodies is very different from those dinas materials that have already been investigated.

In laboratory conditions bodies were prepared with differing compositions containing from 0 to 10% water glass, and fireclay in the same limits. All the bodies containing water glass also contained a 12%-solution of caustic soda. In all 14 versions of the bodies, eight weighings were prepared, from each of which samples were selected for determining the refractoriness and chemical composition. The refractoriness was determined by the standard method as specified by GOST 4069-48.

The chemical composition of the bodies was: 91.4-98.4% SiO_2, 0.04-3.6% Al_2O_3, trace-0.25% TiO_2, 0.06-2.3% CaO, trace-1.3% MgO, 0.08-1.73 Na_2O, 0.04-1.2% Fe_2O_3.

Figure 1 shows the relationship between the refractoriness of the bodies and the concentration of SiO_2 and Na_2O, without taking into account the quantities of residual oxides. The reduction in the refractoriness of the body as a result of diluting the silica with additives agrees well with the well-known statements on the formation in this case of fusible silicates, which during the tests of the refractoriness, at relatively low temperatures, flow from the cone, and thus reduce the stability of the pyroscope. Accordingly, an increase in the concentration of sodium oxides and calcium oxide* also causes a marked reduction in the refractoriness of the bodies (see Fig. 1). However, the affect of the oxides of the alkaline metals is more strong, which is due to the nature of the phase diagram for the system Na_2O-SiO_2, and is confirmed by earlier investigations [1, 6, 7].

The experimental data on the effect of the body composition was processed by the least squares method [8] in the form of linear equations of the type

$$t_{pyr} = A + B\,(\%\,R_nO_m), \tag{1}$$

*Here and subsequently by the term "Na_2O content" we understand the total oxides of soda and potassium which are not separable in chemical analysis.

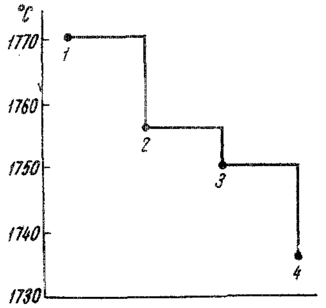


Fig. 5

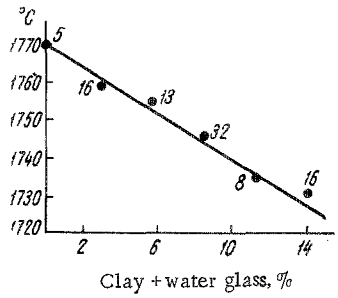


Fig. 6

Fig. 5. Change in the refractoriness of siliceous body with the incorporation of additives. 1) Quartz sand; 2) 5.6% fireclay; 3) 2% sodium hydroxide; 4) 5.6% water glass. The refractoriness values at each point on this diagram are averages of 5 samples.

Fig. 6. Relationship between the refractoriness of the body and the content of clay and water glass in it. Notation at the points on the curve indicate the number of samples studied.

where t_{pyr} is the refractoriness, °C; A and B are empirical coefficients; and (% R_nO_m) are the contents of oxides in the mixture, %.

The results given in Table 1 indicate a reliable relationship between the refractoriness of the body and the contents of Na_2O, SiO_2, and CaO.

However, if for sodium oxide and silica the degree of reliability of the relationship is sufficiently high ($\sigma_r \gg 3$) then for the calcium oxide the magnitude of the ratio of the correlation coefficient to its error only slightly exceeds the theoretically required level. The effect of each of the residual components of the body (Al_2O_3, TiO_2, MgO, and Fe_2O_3) was not studied separately.

Since the greatest action on the refractoriness of the body is exerted by sodium oxide, and its concentration in the bodies was altered in appreciable limits, the more precise evaluation of the influence of the other constituents necessitated splitting the resulting data into three groups with reference to the contents of Na_2O: ≤ 0.5; 0.51-1.0; and 1.01-1.5%. The results of processing the data for the groups are shown in Figs. 2 and 3. If the nature of the effect of silica on the refractoriness in all cases is identical (see Fig. 2a), and is practically no different from the relationship without taking into the sodium oxide concentration (see Fig. 1), then the effect of calcium oxide is noticeable only with a concentration of Na_2O of more than 0.5% (see Fig. 2b). For these ranges a closer relationship is obtained between the refractoriness and the content of CaO. Thus, in the range of Na_2O 0.51-1.0% the value of σ_r for CaO proves to be equal to 5.51.

A reduction in the refractoriness of the silica as a result of the combined influence of CaO and Na_2O with a content of Na_2O greater than 0.5% is confirmed by certain other researchers. Thus, according to D'yachkov [9] dinas mortar containing 8% ground chalk had a refractoriness of 1620-1630°C. With the combined addition of 8% ground chalk and water glass (1.5% Na_2O), the refractoriness dropped to 1510-1580°C. In these studies it was shown that the dinas mortar containing 1-2% fluorspar had a refractoriness of 1680-1690°C, and with the combined addition of fluorspar and water glass (1.5% Na_2O) the refractoriness dropped to 1620-1630°C.

The construction of relationships between the refractoriness of the body and its chemical composition in the low soda-content ranges showed that the effect of MgO on the refractoriness of the body (see Fig. 3a) is almost identical to the effect of CaO. With a concentration of up to 0.5% Na_2O the magnesium oxide slightly affects the refractoriness. With a concentration of 1.01-1.5% Na_2O even a small increase in the quantity of MgO in the body (from traces to 0.5%) markedly reduces the refractoriness. The reliability of these data is supported by the rather high value of σ_r, which is equal to 4.06.

Figure 3b shows that the Al_2O_3 reduces the refractoriness of the body only with a low concentration of Na_2O (up to 0.5%). The influence of Al_2O_3 with an increase in the concentration of Na_2O in the body is undetectable. Ferric oxide Fe_2O_3, has a similar influence. The effect of TiO_2 was not detected in any of the groups of bodies investigated.

Thus, with a concentration in the body of 0.51-1.5% Na_2O the refractoriness of it depends on the concentration of Na_2O, CaO, and MgO. This suggests that the siliceous body in the above chemical composition limits can be considered as being a three-component system, $SiO_2-Na_2O-(CaO + MgO)$, totalling the quantity of residual components with the silica content.

In accordance with this, and from the results of the determinations of the refractoriness, a high-silica section was constructed for the mixture $SiO_2-Na_2O-(CaO + MgO)$, and isotherms were obtained at 1720, 1730, 1740, 1750, 1760, and 1770°C (Fig. 4). Using these curves, from the chemical composition of the body, it is possible to determine its suitability for making ramming lining compositions.

It must be noted that in the existing phase diagrams for $SiO_2-CaO-Na_2O$ and $SiO_2-MgO-Na_2O$, the highly siliceous sections with the concentrations of these components under examination have not been described [10, 11].

The results of the studies of the relationship between refractoriness and the body concentrations of Na_2O, CaO, and MgO suggest that in these limits of concentration these oxides have a linear influence on the refractoriness. Therefore it is possible to expect a linear relationship also in the 4-component system:

$$t_{pyr} = a + b\,(\%\,Na_2O) + c\,(\%\,CaO) + d\,(\%\,MgO), \tag{2}$$

where t_{pyr} is the refractoriness of the body, °C; $\%\,Na_2O$, CaO, MgO are the contents of oxides in the body with SiO_2, % by weight, and a, b, c, d are constants.

As a result of processing the experimental data in the form of Eq. (2) a quantitative relationship was obtained between the refractoriness and the composition of the body:

$$t_{pyr} = 1803 - 40.26\,(\%\,Na_2O) - 8.38\,(\%\,CaO) - 58.88\,(\%\,MgO) \tag{2'}$$

Comparison of the calculated values obtained from Eq. (2') and the experimental data showed that the average error is 8.5°C too low or 0.49%, and 9.85°C too high or 0.57%.

It is possible to recommend the following chemical composition for siliceous bodies for use as ramming materials for lining acid arc steel melting furnaces: 95-97% SiO_2, 1.0-1.1% Na_2O, 1.0-2.5% Al_2O_3 + TiO_2, not more than 0.5% CaO, not more than 0.3% MgO, not more than 0.6% Fe_2O_3, loss on ignition 0.8-1.2%.

The effect of the chemical composition of the body on its refractoriness needs to be taken into account in determining the quantity of water glass, caustic soda and fireclay, since they all contribute oxides to the body tending to reduce the refractoriness.

With the incorporation of each additive the refractoriness of the body is reduced. Figure 5 shows the change in the refractoriness with the incorporation of additives, and Fig. 6 the relationship between the refractoriness and the content in the body of clay and water glass.

Comparing the relationships obtained from a study of the technical properties of the bodies [5] and from a study of the refractoriness, and knowing the chemical composition of the components, it is easy to select concentrations of each of them for the bodies.

As a result of the investigations carried out at the Kharkov Elektrotyazhmash Factory, for ramming linings of acid steel furnaces, bodies were introduced with the following chemical composition: 6% sodium silicate with a modulus of 2.6-3.0, 4% Chasov-Yar clay, 2% caustic soda (12% solution); the remaining materials were Staroverovsk quartz sand from the Vishnevsk quarry. In selecting the body composition it was borne in mind that the fireclay contributes to the mixture oxides that tend to depress the refractoriness (soda, calcium oxide, and magnesia); therefore the minimum content of clay required for obtaining the required technical properties of the mixture was used [5]. The quantity of water glass was determined on the basis of the maximum permitted concentration of Na_2O ensuring a refractoriness of not less than 1740°C in the mixture.

The refractoriness of the body of this composition was 1740-1750°C, that is 20-30°C higher than the refractoriness of electric furnace silica brick and as specified by GOST 1566-50; and the body was introduced for ramming linings of 5 ton arc furnaces of the type BS-5M with a rolling chassis and for furnaces with a capacity of 0.5 ton with stationary hearths. All the furnaces had a cylindrical housing and vertical walls.

The dimensions of the lining of the walls are maintained only by a weekly cold fettling of the discharge pans (during the working week the furnace operates in 3 shifts). The hot fettling done after each heat on the walls has been discontinued. The campaign of a single 5 ton furnace with the rammed walls was 11,347 heats and for another furnace 13,022 heats. After this the furnaces were stopped for major repairs due to the need for replacing the housing. In furnace DS-0.5 some 2513 heats were produced, and the campaign is still continuing.

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