Ferro Alloy Industries in the Liberalised Economy
Editors : A.K. Vaish, S.D. Singh, N.G. Goswami and P. Ramachandrarao
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Cost–Effective Quality Refractories for Ferro–Alloy Smelting Furnaces

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ABSTRACT

Ferro-alloy smelting furnaces are electrothermic in nature where various alloys are produced. Lining of these furnaces with cost-effective quality refractories is an important factor for attaining longer campaigns, better productivity and lower cost as well. Selection of refractories for the lining of these furnaces is based on the methodology of smelting practice, the characteristics of slag and alloy compositions. The development of these refractories for lining of ferro-alloy smelting furnaces has been rather very sluggish as compared to blast furnaces and steel making vessels. Most of the ferro-alloy smelting furnaces use conventional refractory lining used about three to four decades ago. The main reason with respect to this is that furnace loads were relatively low as compared to the dimensions of the furnace. At present, the need for increased furnace availability has forced the refractory manufacturers to develop cost-effective quality refractories.

In this paper, an attempt has been made to highlight the R&D work carried out at NML regarding high alumina refractories and carbon bricks from indigenous raw materials. Super duty fire clay bricks or high alumina and alusite bricks are presently used in the side lining which is prone to alkali attack and carbon monoxide disintegration. The hearth bottom, hearth walls are invariably lined with carbon bricks and blocks, due to their properties suiting the operation of the furnace. The refractory sub-hearth which is below the bottom hearth and plays a very important role in the campaign life of the furnace is lined with 80-90% alumina bricks. Refractories for lining tap hole, runner and plug for smooth production of ferro alloys have also been described in this paper.

Keywords : Quality, Refractories, Smelting, Furnaces, Lining.

INTRODUCTION

Ferro-alloys are of iron and other elements viz., Si, Mn, Cr, Mo, V etc., which are produced leading to their end uses in iron and steel industry depending on the various chemical aspects. The common ferro–alloys are Fe–Si, Fe–Mn, Fe–Cr, Fe–Mo and Fe–V. The furnaces used for ferro–alloy production are mainly electrothermic in nature where graphite electrodes are used to produce electric arc resulting in generation of heat and thereby helping in the smelting process. The smooth running of the ferro–alloy furnaces is controlled by proper selection of refractories for lining apart from other mechanical and electrical parameters. The selection of refractories depends mostly upon smelting practice and characteristics of slag and alloy compositions. Good quality refractories for ferro–alloy furnaces should have (a) chemical composition compatible with that of alloy and slag, (b) low apparent porosity, (c) high bulk density, (d) high softening point i.e., PCE, (e) high strength and (f) high thermal shock resistance. The concept of cost–effectivity means such a cost of the refractory lining that a higher productivity and longer campaign life of the furnace are obtained which result in an ultimate low cost per metric tonne of the alloy produced. During the last four decades or so mostly the conventional refractory lining was being used in these furnaces which may be due to a comparatively slow R&D as compared to Blast furnaces and steel making vessels. The reason for this slow development may be due to a sluggish evolution in the demand of ferro–alloy and thereby the size of the furnace. With the increase in capacity of the furnace, the refractory manufacturers are being forced to produce quality refractories with their cost–effectiveness to use in the lining of ferro–alloy furnaces. This paper highlights some of the cost effective quality refractories viz., high–alumina refractories, carbon refractories based on the R&D work carried out at NML. Other quality bricks used in different parts of the ferro–alloy furnace have also been discussed.

SELECTION OF REFRACTORIES

Side Lining

Fireclay bricks are normally used in side lining (back/cold face) above carbon hearth. The B.I.S. specifications for these are given in Table 1. For hot face in the side lining, high alumina bricks containing more than 45% Al_2O_3 are used on which a good amount of R&D work has been carried out at NML and the properties are given in Table 2. These bricks should possess (i) low apparent porosity (ii) high strength (iii) low creep value (iv) high vol. stability (v) high resistance to chemical attack and (vi) high thermal shock resistance to achieve

Table 1 : Properties of fireclay bricks

B.I.S. No.	Al_2O_3 Min	SiO_2 Max.	P.C.E.	App. Porosity %	C.C.S. kg/cm²	P.L.C. % at 1350°C for 5 hrs. max.
6–1967/1983	30	65	30	25	200	1.0
7–1967/1980	25	70	27	30	150	–
8–1958/67/83	40	–	32	30	175	1.5

high performance during use. Properties of the bricks are related to the development of intergranular bond, lowering of the glassy phases and increasing the crystalline phases which are controlled by the use of quality raw materials with proper calcination etc.

Table 2 : Properties of high alumina refractories

Properties	A	B	C	D	E
Al_2O_3 %	min. 45	54	60	70	80
Fe_2O_3 %	max. 2	1.5	1.4	–	–
A.P. %	max. 18	22	23	25	25
B.D. g/cc	min. 2.10	2.25	2.5	2.70	2.75
CCS, kg/cm²	min. 400	450	350	450	400
RUL, 2 kg/cm², ta°C	min. 1480	1480	1450	1470	1470
Spalling cycles (BRRA)	min. 30	30	30	30	30

The upper part of the side lining deteriorates due to disintegration of CO and alkali attack. Fireclay bricks with high Fe_2O_3 content and calcined at lower temperature disintegrate at about 500°C in CO atmosphere thus prohibiting their use in this part of the lining. Super duty fireclay bricks fired at higher temperature (>1450°C) and andalusite based high alumina bricks having App. porosity 15% max., Fe_2O_3 1.5% max., are now a days used in this section with better service performance. Andalusite bricks with higher alkali resistance are ideal for ferro–alloy furnaces but as the indigenous availability of these bricks is rare we have to go presently for high alumina bricks or importing andalusite bricks.

Hearth Lining

Almost all types of ferro–alloy furnaces have hearth bottom and hearth walls lined with carbon blocks. The reasons for using carbon blocks are (i) high resistance to load at high temperature, (ii) high strength at elevated temperature, (iii) low wettability towards metals and slags, (iv) low thermal expansion coefficient i.e., higher volume stability and (v) varied thermal conductivity over a wide range of temperature.

The properties of carbon blocks/bricks are controlled by the use of proper dry aggregate viz., coal, coke, calcined petroleum coke, anthracite coke and binders viz., tars and pitches. Properties of carbon blocks/bricks are given in Table 3. Petroleum coke based bricks although have very low ash content are weaker and less abrasion resistant as compared to anthracite coke and coal/coke based bricks. Binders also play a major role in contributing to the properties of the carbon bricks. A medium hard pitch or a blend of hard pitch and tar are usually used. In designing the size of the carbon blocks and bricks proper

Table 3 : Properties of carbon blocks/bricks

Properties		Coal Coke	Calcined anthracite	Petroleum coke
App. porostiy, %		13	10	13
B.D., g/cm^3		1.61	1.53	1.68
App. Sp. gravity		1.90	1.71	1.95
Abradability index (Morgan–Marshall scale)		50	70	90
% P.L.C., 2hr. at 1500°C		0.6	0.2	0.2
C.C.S., kg/cm^2		1,130	1,050	770
Oxidation Resistance:				
Air @500°C-1 lit/min		9	15	20
CO_2 @1000°C-1/2 lit/min.		26	30	45
Thermal conductivity :				
K.Cal/m^2/°C, Mean Temp.°C	200	4	3.5	4.3
	400	4.5	4.0	4.8
	600	5.0	4.5	5.1
	800	5.1	4.7	5.3
Ash, %		6.5	5.5	0.5

attention is given to have the least number of joints. The hearth blocks are to be laid in such a manner so that the lengths run in one direction only. A well designed carbon lining has a very long life of the order of 5 to 7 years and with patching work a further run equally long lasts. A poorly designed lining may leak or burn out under adverse operating conditions in a few days. For patching work, carbon paste is used which is cheaper than shaped, baked and machined blocks. The carbon paste is also used as the working lining adjacent to the carbon blocks.

Carbon blocks and ramming masses (paste) are usually based on gas–calcined (1350–1500°C) anthracite. During its use in Fe–Si and Si–metal furnaces, due to certain partial alkali gas pressure buildup, alkali gas penetration into the carbon hearth may cause graphitization of the hearth and thus increasing the thermal conductivity. Cooling of the furnace bottom is the only measure of stopping metal penetration downwards.

Tap Hole, Runner and Plug

Ferro alloy furnaces usually have two tap holes, one for the alloy and the other for the slag. In some cases there are two tap holes for alloy only. Lining of tap hole is made with a carbon block with the cavities around i.e., between the fillings, blocks and linings are filled with carbon (anode) paste. The runners which have two parts i.e., the one adjacent to the alloy receiving end being known as trough and the other part away from it, the runner. The trough is lined with carbon blocks and the runner fire bricks followed by covering with tamping carbon paste. Ceramic plugs for closing the tap holes are now–a–days replaced by carbon plugs which have high spalling resistance, less attack by molten steel, no disintegration and inclusion in steel.

CONCLUSION

Refractories with improved properties give higher lining life than with the conventional types of refractories. The higher lining cost takes care of the high productivity and gives longer lining life.

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