Mill house refractories

B. N. Panti & N. R. Sircar
Central Glass & Ceramic Research Institute
Calcutta-700032

Introduction

Some of the important aspects involved in designing a furnace relate generally to (1) robustness of construction (2) ease of control, (3) ease of maintenance and (4) maximum utilisation of heat energy produced in the furnace. With a view to ensuring improved performances, the reheating and heat treatment furnaces are now being designed as complicated and precise units in place of simple brick-lined boxes, hitherto employed. The demand on the quality of refractories for application in the different zones of such furnaces have become increasingly stringent.

The present paper deals with the development of improved quality of refractories vis-a-vis application in reheating furnaces and soaking pits.

Selection of refractories

Refractories used in heat treatment furnaces are usually employed in two general ways ; (1) bricks and shapes, and (2) castables and ramming mixtures.

The selection of refractories for a specific application has to be guided primarily by the abusive action likely to prevail in operation. Since chemical attack, slagging or melting can completely destroy a refractory material, relative resistance with respect to these aspects needs consideration. Again, the physical stability of a refrac-

Various aspects of selection as well as the present trend of requirement of refractories for reheating and heat treatment furnaces have been elucidated. Developments vis-a-vis applications of refractories in different zones of the furnaces have also been indicated in the context of environment likely to prevail and to be encountered. Characterisations of some of the products developed at CGCRI have been made through conventional test procedures. The properties are quite comparable with those used in foreign countries. In the absence of any dependable test method for measuring resistance of abrasion, thermal shock and creep behaviour at elevated temperatures, proper evaluation of these refractories are considered to be extremely difficult. It is felt that standardisation of procedure for determining these properties is essential in order to ensure improved performance in service. Efforts are now being made at CGCRI to develop these tests.

tory structure is susceptible to applied compressive and tensile stresses, as also to stress induced by permanent volume changes in the refractory mass at elevated temperatures. A reasonable immunity is accordingly vital with respect to mechanical abrasion, as well as thermal and mechanical shock. Besides, specific heat, thermal expansion and thermal conductivity are also important for adjudging the behaviour of refractories as materials of construction.

Certain characteristics of both chemical and physical nature can be anticipated from the phase equilibrium data of the refractory oxide systems. During use, however, refractories usually encounter some reactive materials in the form of slag, vapour or furnace charges so as to complicate the physical and chemical reactions. The crystal-liquid relationships in the relevant systems are of special significance in understanding the ability of the refractory material to maintain its identity when heated, or its stability when stressed. Particularly, the viscosity of the liquid phase and the degree of solubility of the crystalline components in the liquid phase have a great influence.

An ideal selection of refractories would thus be one that may comprehend a techno-economic advantage through a reasonable compromise amongst properties of the refractories in relation to conditions in service.

Property requirements of refractories

In the mill houses, the refractories should have the ability to withstand, without spalling, the operating temperature as well as rapid heating and cooling cycles, often, peculiar to the operation. The loss of heat through the furnace walls may be minimised if the refractories have a low thermal conductivity and a low heat capacity. The furnace may then be heated or cooled rather rapidly, restricting thereby the loss of heat due to storing in the refractory structures.

A high thermal capacity of refractory, is however desirable in case of soaking pit where the roofs is often removed to charge and discharge the ingots. The discharging is usually carried out at high temperatures and repeated opening of the roof-cover may cause chilling of the stock in a furnace of low heat capacity. In such cases, the use of multi layer wall is helpful to meet the requirements of good insulation and mechanical resistance. The main factors[1] influencing the choice of refractory material are—

- (i) maximum operating temperature
- (ii) heating cycle
- (iii) extent of impingement of flame on refractories and
- (iv) contact between the charge and the bricks particularly in the hearth region

Refractories for different zones

There are three main subdivisions in heat treatment furnaces viz (a) hearth or bottom (b) side walls and (c) roof or cover.

Hearth: Refractories employed in the construction of hearth must possess the ability to withstand furnace load over a definite range of temperature. They must be wear-resistant against abrasion and impact of heavy work pieces. They should be inert against corrossive atmosphere and should ensure in some applications, a fair conduction of heat.

The majority of refractory hearths are constructed with dense, high-duty or super-duty fireclay bricks bonded with mortar. The operational temperature being in the range of 1200° to 1450°C, the attack of mill scale with fireclay refractories may be such that the ingots stand in a pool of FeO-Al_2O_3-SiO_2 slag Bonded silicon carbide, fused alumina, magnesite and chrome-bricks are employed when special applications warrant the use of the unique properties possessed by these refractories. Of late, magnesite, chrome-magnesite or 70 to 85 percent alumina bricks are found to be most effective in the hearth and lower parts of soaking pit and reheating furnaces for their inertness to FeO attack. A layer of coke breeze may also be used to protect the refractories from the molten scale.

In some furnaces, rammed hearths have been used and in such cases, proper refractory mixtures which become mechanically strong and highly resistant to abrasion must be employed. Usually, in large car-bottom heating furnaces, the hearths are cast with air-setting refractory mixtures over several courses of hard-fired bricks.

Side walls: The class of refractories mostly employed in side walls of oil and gas-fired heating furnaces are fireclay brick bonded together with mortar, and backed with at least one course of insulating brick, when necessary. The type of fireclay bricks depends on the temperature range and the kind of fuel used. A dense refractory is recommended for furnaces constructed to store heat, while those requiring quick heating and cooling are usually lined with insulating fire bricks. High Alumina bricks are used in cases where the flames come in contact with the side wall.

The working face of the side wall may be built with good quality fireclay (35-42% Al_2O_3) bricks or with semi-silica bricks. Alumino silicate refractories are preferred if corrosive heating fuel is present. With an alternate course of insulating fire bricks is advisable in case significant amount of carbon monoxide or hydrogen is present in the furnace atmosphere.

In lower side walls of soaking pits and reheating furnaces where the refractory is subjected to the corrosive action of molten oxide scale, chrome magnesite, magnesite or 85% alumina brick or 85-95% alumina plastic mass is set into the walls. The side walls and division walls are available, in recent times, in modular type construction in which the large blocks are secured with prefixed anchors so as to save much time and labour. The lower wall is often lined with metal encased, chemically bonded magnesite-chrome brick wherever usual mode of brick laying is followed. Of the burnt type of bricks, the hard burned is preferred. Direct bonded basic bricks have also been tried. Even high alumina, (70% or above) brick has provided good results in the lower walls of some pits.

Burner blocks and parts: Burner blocks are rammed to size with castable mode of refractory cement and high alumina aggregates for withstanding severe conditions. These are placed in position in the furnace as a unit and then bonded to the walls with proper insulation or high-duty fire brick. The composition in terms of Al_2O_3 in the refractory cement depends on the intensity of heat to which the burner blocks are subjected.

Roof or cover : The tops of pits or covers are receiving careful attention since a close seal is required to save the precious fuel. As the covers are frequently drawn aside to allow the charging and removal of ingots, they are subjected to considerable thermal shock. Volume stability combined with spalling resistance are the most important factors that are to be taken into consideration. A superduty fireclay plastic coping has found good applications as it will not crack readily. Because of relatively high cost of fuel, mouldables and castables combined with proper insulation are likely to be used in increasing quantities in these regions.

Waste heat recovery

In the context of fuel crisis, there is a need for some mode of waste heat recovery. Without it, the waste gases leave at a temperature equal to or higher than that of working pieces causing a loss of energy. The addition of regenerators or recuperators is thus a prudent approach.

In regenerators of soaking pit furnaces, dense high-duty fire clay bricks are preferred for checker chamber and checkers themselves. For flues and flue connections, medium-duty fireclay bricks are used. Certain intricate shapes used in recuperator construction have been made of high alumina fire bricks, although in more recent constructions, silicon carbide shapes are used in the hotter regions.

R & D acitivities at CGCRI

Developmental : Central Glass & Ceramic Research Institute in the persuit of improvement in the quality of refractories or import substitution under different projects developed[2—10] several refractories that can be utilised satisfactorily in heat treatment furnaces. Properties of some of these products, as shown in Table I, are quite comparable to those of some selected bricks (Table II) that are recommended for soaking pits and reheating furnaces.

The role of the processing variables, be it composition, forming pressure or firing temperature is critically important in attaining a satisfactory combination of desirable characteristics. The under fired bricks made out of relatively pure raw materials or the overfired products of indifferent compositions are equally prone to premature failure. A special care is thus called for towards judicious selection of raw materials and optimum processing thereafter.

Quality control : Years' of experience with testing of refractories at the CGCRI indicates an overall improvement in the indigeneous supply. The evaluation, in terms of determination of conventional properties e. g. porosity, cold crushing strength and the like, does not adequately ensure satisfactory performance particularly since the operational abuses are not safeguarded in the excellence of such characteristics. Effors are, therefore, underway towards developing suitable but dependable method of determining resistance towards corrosion, erosion, abrasion, thermal and mechanical shock.

The inter relationship of the bond and matrix as may be deciphered in microstructure studies and creep characteristics is considered to bear a significant bearing on ultimate behaviour in service. A systematic probe is in progress for a comprehensive understanding of thermo-mechanical properties of refractories so that the extent of liquid tolerable for a specific application may be optimised. Such a study is likely to provide a guide towards assessing the quality of the product in terms of spatial distribution of the phases. The role and the sum total of desirable characteristics quantified in terms of creep rate.

It is believed that refractories satisfactorily characterised in terms of the above attributes will be much less prone to failure obviously because the tests simulate closely the operational conditions.

Conclusions

Refractories at the mill houses are often subjected to abrasive action when these are rubbed at elevated temperature and are in contact with solid in motion, either in the form of steel ingots or slabs or dust in gases. No dependable test method has yet been adopted for measuring resistance of abrasion, thermal conductivity, creep beheaviour at elevated temperature and specific heat. Proper evaluation thus becomes extremely difficult. The present mode of evaluation through conventional tests appears to be inadequate towards ensuring satisfactory performance. For, performance concurrence has to be necessarily based on simulative conditions.

Efforts are now being made at CGCRI towards standardising some of the testing methods. There has however, been a reasonable improvement through years in the quality of indigeneous availability of mill house refractories. The research effort in the country is also alive in the task of improvement of product through innovative measures and judicious utilisation of depleting resources of high grade raw materials.

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TABLE—I

Properties of some of the refractories developed at CGCRI, suitable for applications in reheating and heat treatment furnaces

Reference-cited	Types	Apparent porosity %	Bulk density (g/ml)	Cold crushing strength (psi)	Permanent linear change on reheating (%)	Refractoriness Under load ta (°C) te (°C)
1	2	3	4	5	6	7
2	Super duty fire brick	16.9—20.4	2.12—2.26	—	1.45—2.08 shrinkage (at 1600°C—4 hrs)	1460—1530 1600 +
3	45% Al_2O_3 —brick (Kaolin based)	19.5—21.1	2.14—2.32	3,674—4,907	0.03—0.10 shrinkage (at 1400°C—5 hrs)	1515—1525 1600 +
4	50—55% Al_2O_3 —brick (sintered Mullite based)	18.2—22.4	2.37—2.16	9,785—13,660	—	1470—1560 1600 +
5	60% Al_2O_3 —brick (Sillimanite based)	12.9—14.9	2.58—2.65	20,676—24,250	0.03—0.14 expansion (at 1600 °C—5 hrs)	1650 1650 +
6	60—65% Al_2O_3 —brick (Bauxite—Chromite based)	11.7	3.27	11,382	1.2 shrinkage (at 1600°C—5 hrs)	1575 1625 (tb)
7	70% Al_2O_3 —brick (sintered Mullite based)	16.0	2.65	9,700	2.2* shrinkage	1640 1640 +

7	70% Al_2O_3 —brick (sintered Mullite based)	16.0	2.65	9,700	2.2* shrinkage	1640	1640 +
8	65% Al_2O_3 —brick (Diaspore—based)	18.0	2.39	8,056	Nil (at 1500 °C—5 hrs)	1555	1600 +
	72% Al_2O_3—brick (Diaspore based)	27.9	2.29	4,177	0.17 expansion (at 1500 °C—5hrs)	1590	1680 +
9	70—95% Al_2O_3 —brick (Bauxite /Tech.Alumina based)	18.2—30.0	2.33—2 84	10,000—25,000	0.06—0.9 Shrinkage (1600—1650 °C—4 hrs)	1580—1635	1600 + 1710 +
7	85% Al_2O_3 —brick (Mullite—Corundum based)	17.0	2.96	9,300	1.25* shrinkage	1760	1760 +
10	Fired Magnesite	23.8	2.67	5,360	0.40 shrinkage (at 1700 °C—3 hrs)	1615	1640 tb)
	Fired Chrome-Magnesite	24.2	2.90	3,530	0.37 shrinkage (at 1700 °C—3 hrs)	1635	1690 +

* Firing shrinkage at 1600 °C

TABLE—II

Properties* of Refractories used in Soaking Pit and Reheating Furnaces

Code	Type	Apparent Porosity (%)	Bulk density (g/ml)	Gold crushing strength (psi)	Permanent linear change on reheating (%)
1	2	3	4	5	6
F1	Intermediate heat duty 25% Al_2O_3	20.6	2.12	4,480	—
F4	Medium heat duty 36% Al_2O_3	22.1	1.97	3,220	0.35 shrinkage (at 1410°C—2 hrs)
F5	High heat duty 42% Al_2O_3	16.5	2.16	5,010	0.01 shrinkage (at 1500°C—2 hrs)
A5	Sillimanite 55% Al_2O_3	12—16	2.35—2.46	10,000+	0.0 to 0.5 shrinkage (at 1500°C—2 hrs)
B5	Bauxite—based high-alumina 80—85% Al_2O_3	17—21	2.82—2.97	8000+	0.0 to 0.7 shrinkage (at 1500°C—2 hrs)
SS1	Semi Silica 9% Al_2O_3	23.6	1.93	1480**	—
C	Fired Chrome-Magnesite	19—23	3.06—3.22	6000	0.3 expansion to 0.3 shrinkage (at 1500°C—2 hrs)
M5	Fired Magnesite	17—21	2.80—2.94	8000+	Nill (at 1500°C—2 hrs)

* As cited by J H Chesters[1]

** Tests on similar brick from different batch.