Recent trends in refractory practices in reheating and heat treatment furnaces*

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It is indeed a pleasure and a privilege to speak to such a distinguished audience. Having worked for a number of years on both sides of the fence, albeit imaginary, of refractory application and manufacture, it is a pleasure for me to see both the groups together in this seminar. Proper co-ordination and co-operation among the refractory manufacturers would make the efforts to achieve better results in the field of refractories easier and quicker. My personal experience in switching sides has been extremely enlightening to comprehend the entire gamut of refractory technology. Of course the tendency on my part to perceptibly increase in physical dimension in latter years, would have made walking in and out of hot furnaces rather inconvenient. Hence possibly the switchover has proved to be advantageous-personally. However if frank and free discussions amongst the different groups lead to better understandings, coordinations and cooperations, then I would be amply rewarded in sharing some of my thoughts on the subject.

Reheating furnaces are used to raise the temperature of steel for plastic working or shaping such as rolling, forging etc. Generally these furnaces are operated above 1100°C. They may be broadly categorised into three major groups as given below :—

1 Batch type or in and out type.

2 Soaking pits.

3 Continuous type which can be further classified on the basis of the transport system of the workload such as

a) Pusher type Furnaces.

b) Walking Beam Furnaces.

c) Rotary Hearth Furnaces.

Furnaces operating at lower temperatures are grouped as heat treatment furnaces viz, Hardening, Annealing, Normalising, Carburizing, Quenching and Tempering Furnaces which are operated usually at temperatures between 450°C to 1050°C These furnaces vary in design depending on the type of charge and other functional requirements.

Refractories in various forms are used as heat resisting constructional materials which make up the chambers of all the furnaces in which heat is generated and transferred to the charge material. They also serve as heat conserving media to economically adopt the process. The refractories used should also maintain structural stability and at the same time be able to withstand the environmental conditions in which they are to function.

The quality of refractory to be used for any particular application would depend on the service temperature and other operating conditions and parameters. One of the most important characteristic of the reheating furnaces is the presence of iron oxide fumes and scales in various states of oxidation. At high temperatures, these vapours have severe deleterious effect on Fireclay refractories due to the formation of low melting phases. Hence fireclay refractories are generally not suitable for furnaces operating above 1200°C, particularly if concentration of iron oxide fumes is appreciable. Inspite of the relative immunity of silica refractories to attack by iron oxide fumes, their low spall resistance puts severe limitations. Hence for high temperature applications, basic refractories are used along with high alumina refractories. In recent years, relatively flux free high alumina refractories are being increasingly used in furnace constructions, operating in higher temperatures and difficult environments.

Another important feature, encountered in the operation of reheating furnaces, is the reaction of iron oxide scales with the free silica of fireclay and high alumina (60% and below Al_2O_3) refractories and subsequent build up due to accrecion of reaction products. Although the detailed mechanism of such reactions require further investigations, it was noticed in the operation of a walking beam furnace with catastrophic results. The problem was subsequently eliminated by the use of properly formulated high alumina (about 80% Al_2O_3) refractories having much less free silica for such reactions.

The refractory requirements for reheating furnaces, particularly for the larger ones are very exacting. The steel maker's concern is high service life mostly due to the fact that any unscheduled shut down in the highly capital intensive reheating facilities would disastrously affect the production programme of the high capacity mills and hence the tendency, specially in other countries, is to use high cost superior refractories having much better technical properties. To feed the modern high output mills the early batch type furnaces with a rated output of 5/10 tonnes per hour have been replaced by multizone pusher furnaces, with higher capacities of upto 200 tonnes per hour. Such higher capacity furnaces no doubt, place increased demands on the refractories. Invariably the requirements are very much stringent in order to ensure smooth operations until a planned shut down is taken since a premature breakdown may badly upset the production schedule. The increased demand on refractories performance by the large output furnaces with extremely severe service conditions has been successfully met by improvements in the quality of usual refractories as also the development of new products.

The furnace builder's concern with refractories relates to the following major aspects :—

a) Conservation of Energy
b) Selection of right type of refractory from the available range of products so as to achieve the desired performance.
c) The design of the refractory lining.
d) Cost.

A) Conservation of energy

About 10% of the total energy consumed per tonne of steel is expended in the reheating operations. Hence major improvements over the traditionally accepted energy consumption norms, are the prime concern of furnace designers, in view of the present day oil and energy crisis. Fuel can be saved essentially in two ways namely, by insulation and/or by faster working and adoption of either one or both the principles would give a lower energy cost per tonne of product made.

Furnaces may be grouped into two major categories viz. the low temperature furnaces, such as heat treatment ones, and the high temperature furnaces. In case of the former, the function of the refractories is primarily the conservation of energy and hence lightweight refractories of low thermal conductivity find wider application. It is all the more so, in case of the batch type of furnaces, where the low heat capacity of the structure because of the use of lightweight refractories would minimise the heat storage and loss during the intermittent heating and cooling cycles. On the contrary, where the furnaces are required to withstand the more adverse environmental factors, e. g. molten metals, slags, gases, vapours and abrasion due to the impingement of dust or flow of materials, normally dense refractories are more desirable. These are usually surrounded by layers of compatible lightweight refractories of low thermal conductivity with the object to minimise the loss of Energy from the system. However the service conditions more or less dictate the essential features of the design and selection of refractories.

The recent innovation in the field of heat insulation is the development and increasing use of ceramic fibre products. Fibrous materials, whether glass or asbestos, has for many years been used for thermal insulation. The recent development of alumino silicate (and to a lesser degree silica and zirconia) ceramic fibres has extended the range of application of fibrous insulation towards much higher temperature than was possible before.

The various types of fibres which are being increasingly used are given below :-

Refractory material	Fibre type	Max. Temp
Asbestos	Natural	600°C
Rockwool	Lime Silica	800°C
Mineral Wool	B. F. Slag	800°C
Silica	Siliceous Fibre	1000°C
Alumina Silicate	do	1400°C
Alumina	Recrystallised	1650°C
Zirconia	Yttria stabilised	2200°C

Alumino silicate fibres are comparatively resilent and are made from a glass of chemical composition approximating 50% Al_2O_3 and 50% SiO_2

Being exceptionally light and having a very low thermal conductivity the ceramic fibre blankets have been found to be very useful for construction of heat treatment furnaces where the temperature does not normally exceed 1200°C and where no corrosive action of gases, slags etc. are encountered and where little or no abrasive conditions are encountered.

The special advantages of the use of ceramic fibre wall lining in construction of heat treatment furnaces may be listed as follows :-

a) Saving on fuel consumption is considerable.

b) Due to lower heat capacity faster cycling times and thereby increase in furnace production is achieved.

c) Ceramic fibre wall lining gives more usuable space inside the furnace as about half the thickness of conventional lining using insulating firebricks may be used.

d) A ceramic fibre wall lining weighs only 10 to 15% of the conventional brick lining, which means a lower construction cost for the furnace as less structural steel work may be used and no special foundations may be necessary.

e) Installation of Fibre wall lining is much quicker and less labour intensive.

The high temperature limit of usage for most of this material has been set around 1250°C as beyond this temperature higher shrinkage and thermal degradation e. g. stiffening, loss of resiliency and devitrification of the fibres take place. Recently, higher alumina ceramic fibres have been developed, which are claimed to be suitable for continuous use upto 1400°C.

Table—I gives a comparison of some of the typical properties of a commercial ceramic fibre and those of insulating and ordinary firebricks. Fig. 2. shows graphically the remarkable difference in thermal conductivity values of the ceramic fibre, insulation firebrick and ordinary firebrick. Fig. 3 shows a comparison of furnace linings made in

TABLE—1

	Density	Sp. ht. Capacity Btu/1b/°F	Thermal Conductivity Btu/in/ft2/°F/h at mean temperature.				Heat Capacity (Btu/ft3/°F)
			800°F	1000°F	1200°F	1400°F	
Cerafibre	6	0.25	0.71	0.89	1.09	1.33	1.5
Insulating Brick (1000°C Hot-Face)	40	0.23	1.68	1.83	1.97	2.11	9.2
Firebrick	130	0.22	8.8	9.0	9.2	9.3	28.6

three different ways i. e.

i) with ceramic fibre wall

ii) insulating firebrick

iii) firebrick backed by insulating firebrick.

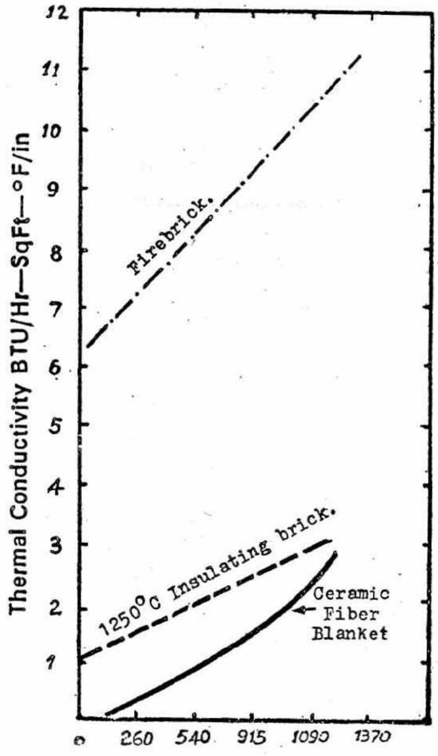

Fig. 2

The comparison shows that for maintaining the same hot face and outside temperatures i. e. 870°C and about 80°C respectively, the fibre wall lining can be considerably less in thickness.

Ceramic fibres, although becoming popular in foreign countries is not yet being used to any large extent in our country, mainly because of indigenous non-availability. Due to the present general energy crisis and high cost of fuels, ceramic fibre as a material of construction appears to have good prospects in our country and production of the same within the country should be seriously considered.

B) Selection of Refractories.

The choice of refractories for any particular application is made with the following considerations :-

1) Area of application.

2) Temperature of application.

3) Abrasion and impact to be encountered.

4) Structural load and load due to the charge in the furnaces.

5) Stress and strain due to temperature gradient in the structures and temperature fluctuations.

desired end result so far as performance is concerned, can be achieved with the available range of materials.

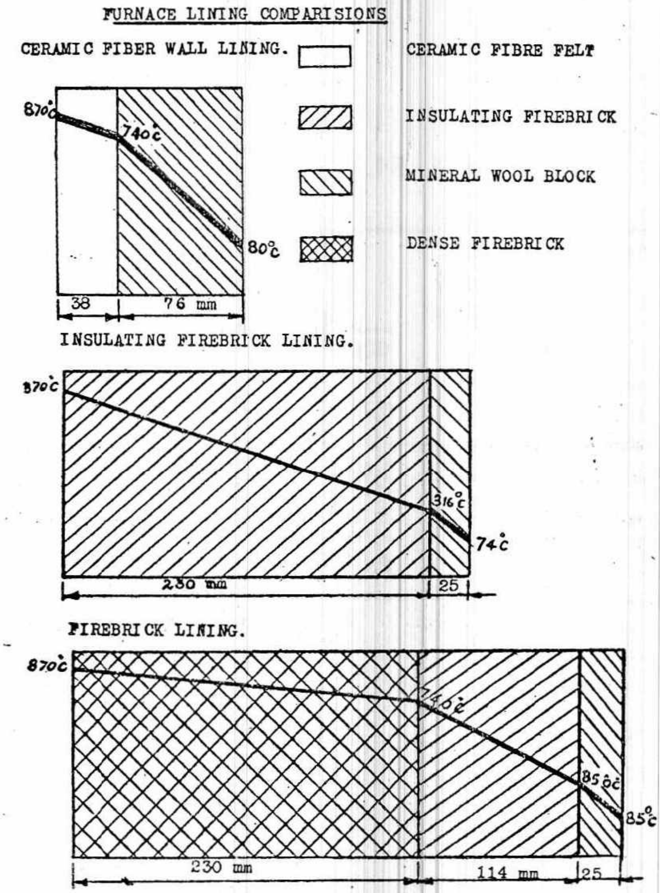

Fig. 3.

6) Chemical compatibility to the furnace environment.

7 Heat transfer and conservation.

Objective evaluation of the above conditions, proper assessment and corelation of the refractory properties to performance are the essential criteria for selection of the right material. The furnace builders have to set up the minimum requirements to meet any particular set of conditions, so that the

Usually the refractories are simultaneously exposed to several conditions during the operation of a furnace, such as high temperatures, flame impingement, structural loads, abrasion and impact due to the charge, corrosive action of the fumes scales and fuel ash and temperature fluctuations. Accordingly the refractories used have to fulfil several requirements for any particular application. A compromise is usually made in that the non-essential properties are sacrificed so that the essential requirements may be economically met.

In reheating furnaces, particularly the heat treatment furnaces the operating conditions are relatively less severe with regard to corrosion, abrasion, erosion etc. Hence hot face insulation bricks may be advantageously used. Recently a large size (22 meter long, 2 meter wide and 8.2 meter high) strip annealing furnace operating at 950°C continuously, was completely relined with specially developed hot face insulation bricks and has been operating smoothly for over one year. The savings in terms of fuel alone has already paid back the marginally higher costs of the bricks several times over.

Similarly the soaking zone hearth of the reheating furnaces provide a critical area which requires attention. The original imported fused cost bricks, which are very expensive, have been successfully replaced by indigenous high alumina fused grain rebonded refractories.

In the soaking pits the conventional fireclay refractories in top layers of the hearth have been replaced by basic or high alumina refractories (80-85% Al_2O_3) to minimise the problems due to attack by iron oxide fumes, scales etc. Such refractories are also used on the bottom portion of the side walls to avoid undercutting, and have been successfully developed indigenously. Similarly the upper portions of the sidewalls, may be, with advantage, replaced by semi silica or spall resistant silica bricks which have also been developed indigenously. Again the traditional fireclay recuperator tubes have been replaced by silicon carbide and recently with zircon tubes with substantially improved performance in relation to the heat transfer. These materials have all been developed in the country and are being successfully used. In the western countries the recent trend is to use large precast blocks or monolithic constructions with ramming masses, castables and plastic refractory materials and are being extensively used in the construction of soaking pits and reheating furnaces. A lot of efforts have been put in our country to successfully develop suitable materials.

However successful use of such monolithic refractories depends to a great extent on the correct application techniques, selection of the proper material and installations. Hence the success would very much depend on closer liason among the furnace builders, operators and the refractory manufacturers.

C) Design of the Refractory Lining.

The various structural elements which are in general common to all categories of furnaces are as follows :-

1 Hearth and working area.
2 Walls.
3 Roofs.
4 Combustion chamber or fire boxes.
5 Flue offtakes and stacks.
6 Regenerators and Recuperators.

Each of the above areas need special attention. A purposeful achievement of this seminar would be to come up with specific problems so that corrective measures may be adopted to improve the performance of refractories in these areas.

With my experience gained over the years, I would fall in my duty if I do not stress the importance of suitable mortars and good workmanship in laying the bricks in achieving better results. The provision of suitably located proper expansion joints also needs emphasis, In the interest of smooth operation of the furnace.

The design of the refractory shapes are also quite relevant to the performance. Proper attention should be paid in designing the refractory shapes so that these can be manufactured easily and perferably in a press and residual stresses during the manufacturing process do not cause the bricks to fail in service. The effect of size of refractories in influencing thermal spalling resistance is well known but unfortunately not enough attention is paid to this aspect in designing refractory shapes.

D) Cost

In the ultimate analysis the performance of refractoies is judged by the overall cost viz. cost of refractories and the service life obtained i. e. the cost per tonne or products made. Usually a compromise is made with the high cost better refractory materials and the relatively cheaper materials which tend to give much less service life. The selection however would be guided by the operating conditions of the particular plant, operational discipline, maintenance schedules and other criteria.

However high cost refractory materials having much better technical properties are being regularly used in other countries, specially for the soaking pits and reheating furnaces of steel plants, thereby achieving a lower overall cost of refractories per tonne of product. We may have to follow the same pattern sooner or later in our country.

The challenge to develop better refractories to improve the performance of reheating furnaces, soaking pits and heat treatment furnaces will surely be taken up by all concerned and specially the refractory manufacturers. The exchange of ideas and experience, identification of problems etc. which will be generated in the course of this Seminar, will, I am sure expedite the process.

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