Refractories for reheating furnace present and future status

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I. Refractories play a very vital role in any integrated steel plant from the stage of coke making to the finished products. With the higher competition in the present world to make steel at cheap and competitive rates with the higher costs in inputs such as raw material, labour and fuel, it has thrown a challenge to all engineers, technologists and designers to construct furnaces for better efficiency and higher output with, less maintenance cost. Dr. Thomas Swinden writing in September 1944, a preface to the first edition of Dr. Chesters well known book, "Steelplant Refractories" pointed out that "we take great care in the designing and building of furnaces, but unfortunately the operating temperatures are often so near to the limiting useful temperatures of refractories that is a constant source of anxiety to get the maximum output and the most of effective operating temperature, without deforming the vital parts of the furnace and destroying or at least reducing its effectiveness. Even though 32 years past, that constant source of anxiety is still with us—indeed perhaps more so than ever with the advent of oxygen blowing processes with computarised controls; Today steel plant operators

With the advent of new processes of steel making, one thing is certain that the steelmaker will continue to demand higher performance from his refractories. By and large this will follow from the present trend towards larger integrated works, in which not only are the individual stages from iron making to billet production, subject to computer control, but also the stages will be subjected to overall control by a Master Computer. The demands for better refractories for reheating furnaces are clear from the fact that such a large 216 inch plate mill of Kawasaki Steel's, Migushima Works in Japan, being the word's biggest with a 3.6 M. T. per year is fully automatic, and under total computer control. The demand for sophisticated refractories further got aggravated by the fact of energy crisis, created recent years by the Arab world, which necessitated the energy conservation. By changing over to new methods such as usage of skid insulations, ceramic fibres, with the recovery of waste heat, the refractory needs a change to the present conditions. At Bhilai Steel Plant lot of things have been done to improve the campaign life of reheating furnaces, with the usage of castables, will be looking for refractories with lives of many months where he now accepts a few weeks so that the refractories of higher quality will be mandatory," Reheating furnaces play a major role in any company's profitability as they have to sustain the loads of different product mix, and work efficiently with less breakdowns and for maximum availability. The refractories face a greater challenge today to meet the new techniques and new processes, For example Kawasaki's steel's Mizushima Works largest but also fully computarised and max. plate sizes of 4.5 to 200mm thick, 1000 to 5300mm wide and length 35 metres and weight of 32 MT are produced in that giant mill of 3.6 Million tons per year capacity. This further increases a challenge to any refractory technologist or engineer to think ways and means of using better refractories which sustain the loads of operation and also to see that the fuel efficiency is the maximum for such units.

II. Even though, the reheating furnaces are different from plant to plant, depending on their design for end products Bhilai Steel Plant, with a capacity of 2.5 MT of ingot steel has the following mills ;-

1 Blooming & Billet Mill	...	28 Soaking pits
2 Merchant Mill 350mm	..	3 reheating furnaces of capacity 60 Tons/Hr. & type end discharging
3 Rail & Structural Mill 350mm	...	3 reheating furnaces of 70 Tons / Hr. capacity and end discharging type.
4 Wire Rod Mill, 250mm	...	1 furnace 120 Tons/Hr. Capacity and side discharging type.

usage of corundum blocks, etc. and with the coming of 3600 mm plate mill under 4 MT expansion, challenges wiil be many for the refractory engineers of the plant. A constant study to have import substitution by usage of jused cast alumina blocks with indigenous, know how is being made to have more self reliance with the better availability of fused cast refractories, castables, and ceramic fibres in our country, the refractory experts of the plant can easily face the future challenges of our country.

In the expansion upto 4 M. T.—3 more reheating furnaces for 3600mm plate mill will be coming up and the mill is under construction. The reheating furnaces in both Merchant & Rail Mill are more or less of same design with different capacities, they are of 3 zones and the refractories used are also more or less same, The major changes that have been incorporated in these furnaces are as follows :—

1. Rationalisation of shapes of bricks used for the burners of top zones, bottom zone, soaking zone and side wall windows.

2. Modifications done for the longitudinal skids supports and lintels on charging & discharging side.

3. Modifications in the specification of refractories used in the periregime roof.

4. Modification to the bottom of soaking zone refractories.

Earlier there were many shapes of burner blocks for these burners of water cooled type and by changing to castables of the specifications in Annexure I these blocks have been eliminated. It was difficult to procure such big blocks from the indigenous manufacturers timely in such small quantities. This not only helped to rationalise the shapes and cut down the inventory, but also help to increase the life of these elements. The longitudinal skids were sagging earlier and there was a tendency for jumping of billets and blooms. This was eliminated by providing extra supports embedded in a refractory castable thus eliminating the brickwork. The periregime or curved roof refractories was giving frequent headaches, as earlier 38 to 40%, Al_2O_3 refractories were used. By changing them to high alumina refractories 54% Al_2O_3 of the specification given in annexure I, these problems were solved and now this zone is giving a life of 2 years. If any brick falls from the periregime roof the hot repairs were not possible because of no approaches from the top of the furnace. The side windows are all watercooled and the design was giving a perpetual problem with various shapes of bricks. This was solved by converting them to segmental arches with the conventional high grog bricks used elsewhere in the plant. The charging and discharging end lintels were giving frequent troubles by the damage due to the billets & blooms and the water cooled lintel used to give way. This was solved by providing T shaped bricks embedded in the T sections over the lintel, and by providing extra pipe support for it. The usage of chrome magnesite refractories for the bottom of soaking zone and bottom zone pillar has helped to remove the built up scale easily through the windows. The life of every element of these furnaces has been improved and today the furnaces are working uniterruptedly for a period of 9 months to one year between the medium repairs.

Reheating furnace in the wire rod Mill :- This is only a single furnace to give a production of 120 Tons/Hour of wire rods. The continuous working of this single furnace is very important for the profitability of our plant. As such every effort is made to have the maximum availability of this furnace. The planned repairs are executed in the year, once in a year a capital repair (for 8 to 9 days) and one medium repair for 3 to 4 days are only done and rest of the time this mill works continuously with only preventive schedule maintenance of the mill. The refractories play a very important place for this furnace alone. Many modifications have been planned and many are under contemplation to match the furnace life. The refractories and mechanicals have to combinedly think to get the optimum life of the elements. These following modifications have helped to increase the life of furnace elements.

1) Usage of high alumina castables (as given in the annexure I) for the burners of top zone, eliminating many shapes.

2) Usage of high alumina 54% bricks for periregime roof and soaking zone burners.

3) Usage of standard high grog bricks for the technological and side wall windows, eliminating many shapes of bricks.

4) Usage of fused cast corundum blocks in the hearth of the furnace in the ejector axis (annexure I).

5) Planning of repairs well in advance, mechanisation of repairs helped to reduce the downtime of the furnace.

6) Controlling the thermal regimes of the furnace with less number of thermal violations.

III. With the higher competition in the international markets, the efficiency and availability of reheating furnaces has become an important part in the saleable steel production. As such the demands for increasing the life of furnace elements for higher availability, and to increase the furnace efficiency has become obligatory on the furnace operation and repair agencies and designers. Sometimes it has become a problem to change over the type of firing and thereby redesign the furnace to the change-over of fuel has become a task for the designers of the plant. With the world energy crisis, and day by day increase in the cost of fuel, the energy conservation and high thermal efficiency are two important factors that no one can ignore. With these objects the refractory technologist of today has to change his views to meet this challenge. It requires for him to change the specification of the refractories, to design methods of mechanisation of repairs for faster repairs, to use insulating castables or ceramic fibres to reduce the heat losses of the furnace, and to think of means to improve element life thus reducing breakdowns.

As a sort of challenge Japanese steel industry faced the energy crisis and reduced the norm of 5.72×10^6 K. Cal/mt of crude steel by 4.6%, already by improving the waste heat recovery, increasing the skid iusulation, providing slab cooling boilers, hot charging and hot direct rolling etc.

IV. In order to use the optimum utilisation of the reheating furnaces at Bhilai, it is contemplated to match the life of elements such as cooled and uncooled skids, and the burner bodies to match with the refractory life. It is thought to have refractory fused cast skids wherever possible, and the burner bodies are air cooled instead of of water cooling. The bottom of the ejector axis hearth of wire rod mill furnace is made with fused cast corundum blocks, and extending the area of this type of lining to heating zone is also being thought of. The insulation of the longitudinal and transverse skids has become a problem to maintain the heat efficiency. This is being changed over to the usage of precast slabs, and thus increasing the life. The increase in the usage of plastics for quick repair and the changing over the bottom to the electro cast corundum blocks in the soaking zone of the Merchant Mill & Rail Mill furnaces is given a major importance. The usage of precast blocks for the walls of the furnaces, and the separation walls of the longitudinal skids is planned for the future. Planning of cold repairs within 10 to 15 days once a year (only for reheating furnaces in Merchant Mill and Rail Mill) with optimum mechanisation for the dismantling & disposal of broken bricks and muck is being planned to get the maximum availability of the furnaces. The usage of Magmalox blocks of specification given in Annexure II & ceramic fibres are in our list of future change over.

V. Ceramic fibre refractories & their uso in Iron & Steel Industry.

The faster growing section of refractory industry is in ceramic fibres which take the form of blankets, rope, rod, mesh, belt and bulk. The present market of these products has increased more than 10-15 million dollars. Until recently these were used as lining material for billet preheat furnaces, slow cooling furnaces, stress relieving, coil annealing and forging furnaces, but their inherent advantages as given below have drawn that products can be used from tundish linings to stopper rod gaskets and coke oven doors. Some of the trade names are Kaowool from Babcock Wilcox Company and MPK Ceramic fibre from MPK Insulation Limited UK. Ceramic fibre is made from kaolin, a naturally occurring. high purity, alumina-silica fireclay containing 45% Al_2O_3 and 52% SiO_2. Babcock & Wilcox melts the kaolin and forms it into individual fibres about 4 to 10" long. The fibres are interlaced in the manufacturing process to form a strong material that needs no binder system. The material is self-supporting—won't sag, settle or separate and can be used at operating temperatures to 2300°F. These following properties of ceramic fibre refractories make them ideal for use in iron & steel industry.

1. Resiliency :- Firebrick and castables are relatively inelastic and when used as a lining, need a massive steel shell to support them and prevent their movement. With resilient fibrous lining, this support requirement is decreased reducing the installation size, and cost of

support materials. Because of its flexibility the fibre lining is able to withstand mechanical shock.

2. No thermal expansion :- Normally firebrick fails with the mechanical abuses or thermal expansion on many occasions. With ceramic fibre materials, individual expansion of the fibre is taken up by the interlocking of the fibrous structures, and therefore there is no cracks, spalling or pinching.

3. Low thermal conductivity :- Ceramic fibre insulation has lower thermal conductivity than conventional linings, so linings can be of half the thickness as those of insulating brick. This certainly helps to redesign the furnace with more operating floor space. Heat storage of a typical insulating firebrick and of Kaowool at 1800°F are 5,497 and 1824 BTU/ft^2/hr respectively. Therefore, heat cycle rate can be increased because heat ups and cool downs are faster.

4. Light weight :- Because Kaowool is 80% lighter than firebrick it takes less time for installation and few labour hours are only needed. This is a major factor in cost savings as it does not need mortar or skilled workmen, and it can be removed very easily without the help of pneumatic hammers.

5. Corrosion resistance :- Because of its pure ceramic nature with no organic binder, kaowool is more resistant to chemical attack than brick. It is completely unaffected by liquid oil or water.

6. Handling ease : Light weight contributes to handling ease. They can be cut to size with a sharp knife.

With the above multi-farious advantages the ceramic fibre refractories are finding place in 1000 furnaces all over the world but as regards the utility of them to reheating furnaces we can discuss here.

Ceramic fibres for skid rail protection :—A major refractory problem in reheat furnaces has been protecting the water cooled skid rails from the terrific impingement on them, and on the billet, from the burners. To reheat efficiently, operators must protect against heat losses to the cooling waters. Under certain operating conditions ceramic fibres blanket can protect as effectively as special brick shapes at a low cost.

One quarter inch wet felt blanket (inorganic binder added) is simply wrapped 4 times around skid rails. Unlike installation of special shapes, there is no need to mortar the fibre to the pipe nor to use studs. Removal is easier than installation and can be done by unskilled workers. Scale is a problem for both ceramic fibres and bricks in the soaking zone. For this reason the fibre blanket is installed in four layers. The savings in cost of ceramic fibre is impressive. Kaowool wet felt cost only

5 to 8 dollars per rft whereas silica alumina special shape cost 70 dollars per rft.

Even though ceramic fibre technology is young, and it is accepted for furnaces working at 1300°C (2372°F) or below where there is no mechanical contact with the lining (i. e. slag or metal) and the fuel is electricity, gas or light oil, still it helps the designers & make full utility. Wherever these parameters permit for fuel economy and faster construction and the need for more floor space under limited conditions.

The largest application to date in the metals field has been on heat treating furnaces and unusual properties of the fibres have revolutionised the furnace design on a rebuild it costs about 40% less to put in a ceramic blanket than to reline with brick.

VI. In view of the expansion programme at Bhilai to 4 MT stage, the problems which are going to be encountered with high capacity reheating furnaces of 3600mm plate mill have been thought and many suggestions to the designers are given for implementation. This includes usage of standard shapes of bricks that are already being used under 2.5 MT for better inventory control, usage of Magmalox blocks for hearths and better insulation system by the usage of ceramic fibre blankets. The main characteristic of the reheating furnace in the 3600mm plate is as follows :—

Type of Furnace	:	Pusher type (continuous)
Capacity per hour	:	120 Tonnes
Size of steel processed	:	l=1700 to 3400 mm, b=1050 to 2000 mm
		t= 130 to 320 mm.
Quality of slabs	:	low and medium carbon steel, low alloy steel
No. of burners	:	46
No. of zones	:	5
Operating temperature	:	1280 °C on top of slabs
Type of fuel	:	Mixed gas/heavy fuel oil
Size of Furnace	:	length 28 metres, width 7.7 metres.
Type of recuperators	:	metallic. Air preheat temp. 500°C.

VII. Fused cast refractories and their importance in reheating furnaces

Of late, we know that the fused cast refractories of various varieties as given in the Annexure II such as Magmalox, corundum blocks are widely used in high capacity reheating furnaces, as they have the following advantages over the high alumina refractories. Magmalox block with a chemical composition of 74% Al_2O_3, SrO_2 4 to 5%, SiO_2 19% to 20% are directly cast into various blocks of sizes 40 to 200 Kg by the fusion process. Their main properties are compact crystalline structure, high refractories, absence of open porosity, high mechanical strength at elevated temperature and high wear resistance whether due to corrosion or abrasion. The additional advantage is of being easy to deslag, hot or cold without damage to the material done to the weak adherence of the oxide layers to Magmalox. These are used in pusher type billet furnace as dry skid rails, soaking zone & discharging zone, ingot and bloom furnaces in the soaking pits where deslagging is carried out cold in the bottom and lower parts of walls.

Corundum blocks in the hearths of continuous furnaces of section mills.

The chrome magnesite brickwork in the solid hearths of the continuous furnaces in the 280, 250 & 350 section mills used for 60 x 60 or 150 x 150 billets upto 12 m long has been observed to wear rapidly (a life of 4 to 5 months) especially where the billets leave the uncooled bars and in the front of the delivering door. With the usage of corundum blocks (93% Al_2O_3) (Annexure I) of wt. 55 to 110 kg. the life of the hearth has increased to 2 years and there is no build up of scale. It is not recommended any expansion joints and also that the blocks should be laid closer to the walls, since when the furnaces are stopped or there is a negative pr. at hearth level the blocks are subjected to thermal shocks and breakdown. Cr. Mg. brick is laid between the hearth block and the furnace wall. The sizes of the blocks are 600 x 200 x 300 mm to 480 x 300 x 200 mm.

Experience of running furnaces with corundum block hearths has shown that water can be used for removing scale deposits from the hearth with the latter at not below 800°C, and this does not shorten the life of the hearth.

VIII. Today's trend to refractories is one in which the steel maker is no longer looking for the cheapest refractory material but rather for the refractory material providing the least cost per ton of product. This change to higher quality refractories has been speeded up by the large increases in fuel and labour costs. The prices of refrac-

tory materials have risen and so have the specifications covering quality of the refractory.

With the growing competition in the world for the cheap steel making, it is obligatory on the part of refractory researchers to identify the problem faced by the steel industry immediately & develop & manufacture fused cast refractories, plastics, ceramic fibres at reasonable rates, and to also to keep a close liaison between the designers, refractory engineers and the manufacturers, such that the import substitution might bring dividends to the nation's economy.

Annexure—I

Specifications of refractories used in Reheating Furnaces of Bhilai Steel Plant

Properties	Fireclay castables	High alumina castables	Properties	Moderate heat duty F/clay bricks (IS-6-1967)	High grog F/clay bricks	Higb alumina bricks for periregime roofs
Setting	Hydraulic	Hydraulic	Al_2O_3 not less than	30%	35%	54%
Sintering remp.	1250 °C	1350 °C	SiO_2 not more than	65%	—	—
Refractoriness	1600 °C	1700 °C	Refractoriness, not less than	1665 °C	1683 °C	1750 °C
Al_2O_3, %	38–42	60/65	A. P not more	25%	17%	20%
Grading in mm	0–4.0	0–4.0	C. C. S. not less than	200 kg/Cm2	250 kg/Cm2	300 kg/Cm2
Application temp.	1450 °C	1550 °C	R. U. L., Ta not less than	1300 °C	1450 °C	1530 °C
			P. L. C. not more than	1% at 1350 °C for 5 hrs.	1.5% at 1550 °C for 1 hr.	

Properties of Electrosmelted cast corundum blocks

Al_2O_3	—	96.15%
TiO_2	—	0.20%
Fe_2O_3	—	0.19%
SiO_2	—	2.85%
CaO, MgO	—	Traces
$K_2O + Na_2O$	—	0.58%
Apparent density	—	3·04 gms/cc

Annexure—II

Propertios of Magmalox—fusion cast alumina refractory

Typical chemical analysis			Typical crystellogrephic analysis		
Al_2O_3	=	74%	Corundum	=	43%
ZrO_2	=	4 to 5%	Mullite	=	37%
SiO_3	=	19 - 20%	Zirconia	=	4 - 5%
TiO_2	=	0.4%	Vitreous Phase	=	15%
CaO	=	0.4%			
Fe_3O_3	=	0.6%			
Na_2O	=	0.9%			

Typical physical properties

Absolute density in block form = 3.00

C. C. S. = 2000 Kg/Cm^2

Hot crushing strength — 1000 Kg/Cm^2 at 1300°C

— 300 Kg/Cm^2 at 1500°C

R. U. L. (2 Kg/Cm^2) > 1770°C

Linear expansion :- 1100°C — 0.73%

1300°C — 0.90%