REFRACTORY LINING FAILURES IN FECR FURNACES AN OVER VIEW

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ABSTRACT

The practice of refractory lining in Fe Cr furnaces is purely based on the behavior of various refractories used in different parts of the Furnace at elevated temperatures.

The choice of the pattern of lining is mostly done on traditionally based concepts.

Refractory Lining of a furnace is the most crucial enabler for operational excellence for Ferro Alloys production.

During the last few years, no major technological change has taken place in 'Refractory Lining Management', only freeze lining concept is becoming popular. Many ferro chrome furnaces today, have the refractory lining problems especially at tap holes, resulting in shutdowns and production losses.

The author with his experiences for the last 37 years in furnaces of all sizes tried to attempt to investigate into the reasons for premature failure of lining.

1. INTRODUCTION

Most of the Ferrochrome producers follow the conventional lining pattern comprising with Alumina bricks and Carbon ramming paste. However, for large furnaces of more than 25MVA capacity, carbon blocks usage in the bottom as well as at the sides has becomea common practice.

Some of the producers are slowly replacing tamping paste by magnesite and high alumina castable blocks for prolonging the lining life. Irrespective of pattern of lining, the Operational Management plays a vital rolein the life. The author's views in this paper are purely personal and based on his experience.

2. REFRACTORIES-PROPERTIES

Erosion of refractory bricks because of high temperatures, Wear of refractories due to chemical attack of slag and development of high thermal stresses are some of the major reasons for the damage of lining. High cold crushing strength, low PLC (Permanent Linear change) and high refractoriness under load are some of the properties to be considered in the selection of refractories.

Selection of refractories is based on the size of the furnace,product mix and availability. The properties of various refractories used in a Ferro chrome furnace is furnished in the appendix. Different refractories are chosen for different areas of the furnace crucible.

For ferrochrome production, several lining patterns are followed comprising with different quality of refractory material

It is interesting to see that Silicon Carbide bricks which are best suited at tap hole area are getting eroded fast in Ferrochrome furnaces. This is the experience of many ferro chrome producers. The same refractories are performing well in Ferro Manganese and Silico Manganese operations. The metallurgical reasons have to be established.

3. FAILURE OF REFRACTORY LINING OF A FERRO CHROME FURNACE

The electric Submerged Arc furnace producing Ferro Alloys is a high temperature reaction vessel. In addition to the temperatures, the furnaces are subjected to other factors that command the life of refractory lining.

As a matter of fact, a Ferro Chrome furnace operates on a pseudo (false) crucible. The latter is gradually formed with the crust inside the furnace. This acts as a protective lining. Sometimes, with the operational problems like slag boils and liquid pool formation, the crust gets dissolved and the liquid slag starts attacking the original lining. The wear and erosion mechanisms start with such operational problems.

After few years of operation, the refractory lining gradually gets replaced by metal & slag especially in the furnace bottom and tap hole area.

The normal refractory life of a small furnace is 6-7 years and 10-12 years for a large furnace because of the pattern of lining used. However, it was noticed, some of the furnaces have premature failure of lining, especially at tap hole area, even in less than one year of operation.

In certain plants, there were disasters because of seapage of lining even at the bottom level. The author tries to explain the possible reasons and the producers need to take corrective measures for the prevention of such failures.

The possible major reasons for failure of refractory lining are

1. Non provision of crucible dimensions with respect to the power input.
2. Inferior quality of refractories in size as well as quality.
3. Non-adherence to the standard procedures during start up and heating periods.
4. Improper control on slag chemistry.
5. Poor tap hole management.
6. Inconsistency in the operations.
7. Poor electrode management.

3.1 Design Aspects

While designing the refractory lining of the furnace, much emphasis has to be given on the crucible dimensions, electrode diameter and pitch circle diameter etc.

Table-1 shows the dimension followed by various plants for the same capacity of transformers.

TABLE 1 9MVA

Item	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
Shell diameter mm	7550	7800	7700	7200	6990
Hearth Diameter mm	5520	5700	5500	5200	4930
Depth mm	2400	2500	2600	2300	2400
Electrode Diameter in mm	950	1000	1000	1050	965

16MVA

Item	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
Shell diameter mm	8300	10000	8400	7800	8840
Hearth Diameter mm	5950	4800	7064	5500	6200
Depth mm	2500	4800	3030	2600	2200
Electrode Dia mm	1125	1100	1100	1100	1100

9 MVA furnace of Plant No. 5 and 16 MVA furnace of Plant NO.4 had lining failure problems within one year of the commissioning. Operating load of all 9MVA furnaces is 7-7.2 MW and all 16 MVA furnaces 11-11.5MW.

3.1.1 Orientation of Tap Holes

This is another interesting parameter. The choice of number of tap holes and their orientation is purely as per convenience and practice. At present the common practice is to provide two tap holes in the front side at 20-60 deg apart. People prefer this for the tapping convenience.

As per the authors experience, nearer the tap holes, faster the erosion of lining in the front side. This has been observed in some of the furnaces. If the distance between the tap hole and Electrode is less, the damage is still more.

Elkem's original design of provision of three tap holes at 120 deg apart is giving benefit to some of the producers.

Even in the large furnaces also with single tap hole in the front side, production can be achieved, provided other parameters are kept as per standards

3.2 Lining Procedure

Even though there are no standard documented procedures are available, the following non conformities are experienced during refractory lining.

- Lack of homogeneity in the size as well as chemical composition of the refractory bricks.
- Lack of adequate laboratory facilities for measuring certain key properties of refractories.
- Improper care taken during paste tamping.
- Poor quality shell fabrication and erection.

4. FURNACE START UP

Furnace start up is the most important aspect of life of refractory lining. Any mistake at this stage would result in problems at later stages of operation.

Plant has to follow a systematic schedule for the preheating of the lining.

The following are the activities in the start up.

- Drying of lining with fire wood. Cleaning and removal of Ash.
- Spreading of coke in the bottom.
- Fixing cylindrical boxes filled with coke under electrodes.
- Electrode tip baking.
- Filling of paste into the casings.
- Testing of all equipment.
- Starting the furnace.

Furnace has to be slowly heated. A load curve has to be prepared for a systematic heating.

Preheating period depends on the size of the furnace and type of refractories used.

The technology developed in the last decade is the preheating of furnace with burners, so as to reduce the un due time consumed in heating.

The following non conformities were noticed during preheating period which will have an impact on the lining.

- Accumulation of water due to water testing and rains on the bottom and furnace start up with out drying.

- Improper load schedules and faster heating.
- In sufficient/ excess coke additions which give problems after start up.
- Electrode breakages because of improper baking, leading to operational problems.
- Improper balance in the initial mixes.
- Improper covering of side lining.
- Charging of the furnace before the attaining required temperatures
- Accumulation of liquid metal and slag in the furnace for longer periods.

Health of the furnace has to be constantly monitored during preheating.

5. CHARGING

After the preheating the initial charge that is taken in the furnace plays an important role. Since lot of coke is added during preheating operation, the first charge mix selection has to be done carefully.

It is noticed most of the furnaces produce either low or high silicon metal in the initial periods. Both the operations are not healthy for lining. Accumulation of liquid slag for a longer time in a new furnce is highly detrimental to the fresh lining.

5.1 Power Loading

It has been observed several producers in order to get production fast, increase the furnace power in put rapidly and land in to problems subsequently.

Higher loads with higher voltages and secondary currents have a direct bearing on the life of hearths.

The lining erosion is faster.

It is worth mentioning, a large furnace which operated on 50-60% of the maximum load for a number of years has completed more than 20 years of life.

Selection of load is an important parameter for a furnace especially which is freshly lined.

Load interruptions/fluctuations may cause damage to the lining with the formation of thermal stresses.

Transformer over loading is a common feature and furnaces get damaged in all aspects.

There are norms for specific hearth loading, ratio of shell diameter and electrode diameter and specific volume load and deviations from the standard values may cause damage.

6. ELECTRODE MANAGEMENT

In submerged arc furnace Electrode management is one of the most important KRA (Key Resultant Area), which completely controls the furnace operation. Maintaining proper lengths of Electrodes, slipping Schedules, current densities and cooling of holder are the important tasks of an operator. It is a well established fact that if the lengths of electrodes are high bottom lining gets damaged in no time. This was experienced in many small furnaces. The distance between the tip of electrode and the furnace bottom is an important parameter.

Some plants suffered bottom seepage of metal which resulted huge losses.

Similarly short electrodes are also dangerous as bottom build up of metal would be there, resulting in tapping problems with slag pools which again are detrimental to the lining.

Breakage of electrodes in Ferrochrome operation are mostly due to poor electrode management.

7. SLAG CHEMISTRY

In Ferro chrome operation slag chemistry plays a major role in the production and other usages like Power, Ore and fixed carbon etc. There are certain standard ratios of oxides and each ratio plays a different role.

Mgo/Al_2o_3 is a very crucial parameter. The quality of metal is related to this.

Silica in Slag is the most important controlling factor for the operation. If silica goes up in slag, the protective skull gets dissolved and the lining starts getting affected.

Better Raw material management with dosing of correct recipe of charge materials is the only solution to avoid such problems.

In the furnaces which are dug out, metal seepage to the bottom of the shell can be seen in some plants (photos.)

With poor slag chemistry tap hole lining gets damaged in no time and create problems in the operations.

8. ERRUPTIONS

In Ferro chrome operation, all the plants in India, use more than 70% of friable ore, in the form of Briquettes or pellets. In the conveying process lot of fines get generated in the furnace. These fines get clogged and reduce the permeability of the charge. Gases cannot escape under these conditions and generate very high pressure inside the furnace and serious eruptions take place. Usage of poor quality of briquettes, direct fines, water leakages from electrode parts and sudden shrinkage of charge etc cause violent eruptions and disturb the linings. This is noticed especially in furnaces with new lining and bricks get lifted up after eruptions.

9. MISCELLANEOUS

9.1 Taphole Management

Large Furnaces having drilling machines for tap hole opening and mud guns for closing, experience better tap hole management than furnaces of smaller size. Usually graphite blocks are used in the former case at tap holes where as tamping paste is used in the latter cases. In both the cases silicon carbide lining is applied.

In many plants tap hole management is given little importance, as a result of which lining erosion takes place in no time. Continuous usage of same tap hole, Excessive lancing, improper closing of the tap holes after tapping are some of the reasons for failure.

Poor slag chemistry and improper tap hole positioning and carrying out tappings immediately after repair with paste are some of the other causes of failure.

Outo kumpu with pellets charge and closed top, prefers a single tap hole where as some other producers suggest two tap holes in the front side. Most of the plants in India are going for this design.

The advantages and disadvantages have to be commented by the individual producers.

Hot spots, bulging of the shell at tap hole area and emanation of flames in the tap hole region are some of the indicators of failure of lining and if proper care is not taken, the situation gets worsened.

9.2 Shell Cooling

Some producers prefer shell cooling and some do not provide. Again the advantages if any have to be claimed by different producers. The Author strongly feels that shell cooling will help in the formation of pseudo crucible in the furnace.

Some understanding of heat transfer is required The lining life may be related with cooling.

9.3 Metal Composition

Silicon fluctuations in metal may cause upset in the operation. Prolonged operation of high silicon metal (5%) may have an effect on the lining. It is necessary to adjust the slag chemistry.

9.4 Alkali Attack

Theoretically this is an important aspect for the failure of lining but no detailed study has been made with Indian raw materials.

10. SUMMARY AND CONCLUSIONS

Even though many factors affect the lining life, the major reasons are design and operational management.

Refractory failures have become very common especially at tap hole areas in small furnaces resulting in production losses.

Furnaces are being designed with out provision of bottom cooling.

Constant monitoring is required of the shell temperatures. It is surprising to see certain furnaces are being installed just above the ground level with out allowing for any air-cooling.

Furnaces are run on pseudo lining. This skull has to be properly maintained for long life.

The abnormal temperatures that get generated due to changes in the slag chemistry and occasional shoot up of Silica in slag start the process of wear of lining.

Bricks getting lifted up at tap hole area, shell bulging,redspots adjacent to tap hole area and self tappings through the tap hole are some of the wake up calls given to the operator for immediate attention.

Friable ores used in Countries like India and South Africa help in forming refractory crust in side the furnace.

The author strongly feels that every industry should have Standard Operating Procedures for effective working for all the key resultant areas like:

a) Electrode Management
b) Raw Material Management
c) Process Control
d) Tapping and Handling area
e) Quality Control

Consistent charge recipes without frequent changes, consistency in furnace availability, load factor and quality would result in better operational management and better lining control

APPENDIX

Specifications of Refractories for a Ferro - Chrome Furnace

Area	Item	Chemical composition	CCs Kg/cm^3	App Porosity%	BD Gm/cc	RUL Ta°C Min	PLC at 1450°C 2hrs
Furnace Bottom	Alumina (40%)	40-42% Al_2O_3 1.6% Fe_2O_3	400	18	2.20	1450	± 0.5
	Alumina (60%)	60-62% Al_2O_3 1.5% Fe_2O_3	300	23	2.4	1550	± 0.2
	Magnesite	87-89% Mgo 10% Max	350	22	2.8	1580	
	Carbon Block	Ash 0.8%	310	16	1.8	2000	0 - 0.09
Furnace Side	Alumina 40	40-42% Al_2O_3	400	18	2.20	14.50	± 0.5
	Carbon Block	0.8% Ash	310	16	1.8	2000	0 – 0.09
Tap Hole	Silicon Carbide	Sic – 85-87% Al_2O_3 – 1.2% SiO2 - 6-8% Fe_2O_3 1.1.5%	1160	17.5	2.6	1700	± 0.05
	Tap hole carbon blocks	15-18 % Ash	380	17.5	1.89	Above 2000°	0 – 0.08
Others	Alumina Castable	55-60% Al_2O_3 2 – 2.3% FeO_3	250	--	2.2	1650	--
	Mortar	55-60% Al_2O_3 30-35% SiO_2					