

Lecture 10: Refractory in steelmaking

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Key words: steelmaking, ladle metallurgy, Electric arc furnace, refractory

Preamble

In steelmaking, refractory materials are used in converter, electric furnace, ladle, tundish, and reheating furnaces. In converter, electric furnace, ladle and tundish, molten steel is in contact with slag, whereas in reheating furnaces steel in the solid form is reheated for deformation processing, heat treatment and surface hardening methods.

BOF refractories

Converter is lined with a permanent lining and above it there is a wear lining. Permanent lining thickness may vary from 100mm to 120mm and is made of chrome-magnesite permanent lining which is given on the full height of the converter.

Above the permanent lining, wear lining is constructed. The cylindrical portion of the converter (barrel) is lined with the ramming mass of tar dolomite and tar dolomite bricks. The detachable bottom is constructed by using mica, fireclay, chrome-magnesite and Mag-chrome bricks.

MgO – Carbon refractory materials with 15% high purity graphite have been found to provide increased corrosion resistance.

In duplex blowing (hybrid blowing or combined blowing) MgO – C bricks are commonly employed for the bottom tuyeres and around them, since these areas severely worn.

The slag and metal penetration between the refractory grains, chemical attack by slag, mechanical erosion by molten steel movement contribute to the wear of the lining materials.

Some developments to counteract this lining wear are:

- i) Dolomite (40% MgO) is added to create a slag of about 8% MgO which is close to saturation level of slag.
- ii) Critical wear zones (impact and top pads, slag tapping and trunion areas) are lined in furnaces with high quality bricks.
- iii) Slag splashing in which the residual slag is splashed by high speed N_2 has resulted into high lining life (refer lecture 14)
- iv) Lowering FeO levels in slag and shorter oxygen-off to charge intervals have reduced refractory wear.

Refractory for secondary steelmaking

There are many operation and process in secondary steelmaking like vacuum degassing, ladle refining etc. Refractories are used in unique combinations of various bricks to meet diversified requirements. Following condition may be noted:

- i) High temperature and long holding times of steel in ladle.
- ii) Wide variation in slag composition
- iii) Many types of vacuum treatment.
- iv) Large thermal changes.
- v) Molten steel agitation causes attack by motion of liquid steel.

In all ladle refining processes such as ladle furnace, ASE-SKF, VAD process, MgO – C bricks are used at areas, where slag is in contact with steel. For general wall, high alumina bricks are widely used. For bottom zircon bricks are used to prevent molten steel penetration into brick joint. In certain cases MgO – C, Al_2O_3 – C bricks and castables are used in impact areas. MgO – C bricks with addition of a couple of metals provides high hot strength, and are excellent in oxidation resistance.

Refractory for continuous casting

Tundish is a refractory lined vessel in continuous casting. It contains molten steel with minimum heat losses. Selection of refractory is critical due to longer casting sequence, faster tundish turnaround, higher campaign life and cleanliness of steel. Fireclay bricks are used. High alumina bricks are considered to be good for tundish hot rotation. Basic coating material is used over the lining. The coating installation method is gunning. Typically MgO – SiO_2 – Al_2O_3 mixture is used as a coating material.

Tundishes are equipped with dams and weirs. There are made of MgO boards or alumina bricks.

Molten steel from tundish to mold is fed by nozzle submerged into molten steel in mold. Submerged nozzles must be resistant to corrosion and spalling, nozzle clogging is also important. Isostatic pressed submerged nozzle with alumina- graphite-fused silica are being used.

In recirculation degassing steel is made to flow from the ladle into a separate degassing chamber. In RH process, a refractory lined vessel equipped with two legs (snorkels) is used. These snorkels are immersed into molten steel. The refractory materials must have adequate spalling and abrasion resistance, volume stability and corrosion resistance at high temperature and in vacuum. Direct bonded magnesia- chrome bricks, semi rebonded magnesia chrome bricks are used in the lower vessel and snorkels. Extra high temperature burned magnesia –chrome bricks possess excellent corrosion and abrasion resistance and are preferred lining material.

Refractory lining for high temperature furnaces

Furnaces are used for heating steel within the temperature range 1000°C to 1200°C for heat treatment and deformation processing. Many different types of furnaces are used namely soaking pits (batch type) and continuous furnaces. Fireclay and high alumina refractories are used. Most of the continuous furnaces are lined with fireclay bricks. Plastic chrome ore ramming mixture and hard burnt chrome magnesite bricks are used to line the hearth to provide resistance to scale.

Emerging trends

Refractory has undergone many changes to meet the diversified requirements of the industry particularly steel industry. The main objective is to increase the lining life at reduced cost by developing

- a) High quality refractory for critical applications in steel making at e.g. slag line, impact area of molten steel stream, bottom tuyere refractory in hybrid blowing, immersion nozzles in continuous casting etc. In this connection mention may be made of some refractory like MgO-C, $\text{Al}_2\text{O}_3 - \text{Si C} - \text{C}$, $\text{MgO} - \text{Ca O} - \text{C}$, Al,Mg and Al-Si alloy stabilized MgO – C brick, zircon based refractory, and $\text{Al}_2 \text{O}_3 - \text{C}$
- b) Repairing methods like slag splashing, slag coating, hot patching, gunning (flame gunning involves melting and spraying on hot surface).
- c) Monolithic refractory

Monolithic refractory

Monolithic linings are a relatively recent development and consist of unshaped refractory products. These are materials which are installed in some form of suspension that ultimately hardens to form a solid mass. There are two basic types of monolithic lining, namely castable refractory and plastic refractory

Castable refractory consists of mixtures of coarse and fine refractory grains together with a bonding agent which is normally based on high alumina cement. Installation of the refractory is important. Due to relatively poor strength, durability of monolithic lining depends on the design and installation of the anchors.

Monolithic linings are installed by casting the refractory in a mould or by spraying the furnace shell. Largest problem with use of monolithic refractories are:

- Long drying time
- Steam explosion.

Furnace refractory maintenance: The following methods are commonly practiced.

Slag splashing

Slag splashing is done in steelmaking vessels. After steel tapping, some amount of slag is retained. Composition of slag with respect to FeO and MgO is adjusted. FeO makes the slag adhesive on the lining and MgO makes the lining high temperature resistant. Nitrogen is blown from top to splash the slag. The splashed slag gets coated on the lining. To reduce excessive slag build up in the bottom, excess slag is then poured before charging.

In case of hybrid blowing practice formation of skull may result in a failure of the bottom stirring elements.

Slag coating and slag washing

The small amount of liquid slag is retained in the vessel after tapping. Slag is enriched with dolomite or raw dolomite to cool the slag and to increase its adhesive properties. Vessel is rocked several times to coat the bottom and bottom joint with a slag.

Hot patching

Self flowing refractory mixtures enable precise maintenance of the scrap impact zone, tapping pad and bottom joint.

Gunning

By gunning, i.e. maintenance of pre- worn areas with special gunning mixtures, vessel lining life can be extended.

Flame gunning involves simultaneous melting of a refractory powder and gunning at the hot surface. Since the gunned repair material is dense and fused directly on the hot surface excellent results on life of lining is obtained in LD converter.

Future issues of Refractory technology

1. Durability of refractory for pairing nozzles and side dams determines the success of strip casting.
2. Technology of mass melting of scrap in converter by using post combustion requires super- high temperature refractories.
3. Super fine powder processing technology to produce refractory.

4. Use of monolithic refractory in steel making and refining furnaces require automating brick lying and intelligent repair.
5. Nano tech refractory is thermal shock and corrosion resistant The nano-particles act in two ways
 - They consist of mono spheres and improve properties like elasticity and strength
 - Control of molecular structure as the particles have many small pores of several hundred nanometers.

Reference:

P.Mullinger and B. Jenkins: Industrial and process furnaces

Kenneth C. Mills et.al.: A review of slag splashing, ISIJ Intern. 45(2005), No. 5, PP 619-633

Y.Naruse: Trends of steelmaking refractories

Assignments based on lecture 9 and 10

- 1) What do you understand by the spalling tendency of a refractory brick? Give reasons.
- 2) What is meant by refractoriness under load? What is its importance?
- 3) Explain the term inversions in relation to the behavior of silica brick on heating and cooling.
- 4) Silica bricks are manufactured from a naturally occurring quartzite, which contains 98% SiO₂. Is it possible to use these bricks without any thermal treatment?
- 5) High alumina bricks are better than fireclay. Why?
- 6) High magnesite refractory show good resistance to attack by iron oxide. Why?
- 7) Why is it necessary to add anti-shrinkage material for the manufacture of fireclay bricks from naturally occurring clay ores?
- 8) How are insulating bricks manufactured?

