

Lecture 14 Modern trends in BOF steelmaking

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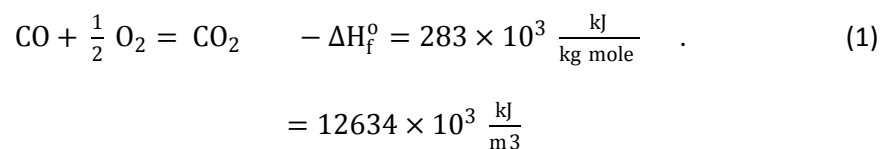
Mechanism of slag carry-over

Key words: Post combustion, slag splashing, slag carry-over, slag free tapping

Post Combustion

The oxidation of carbon to CO in BOF steelmaking is the principle reaction. In converter steelmaking CO produced during refining exits the furnace in exhaust system where it is combusted with the ambient air.

Combustion of CO to CO₂ produces large amount of thermal energy



Thus post combustion of CO in BOF and transferring the heat of combustion to the slag and metal offers an additional amount of energy. The amount of post combustion taking place in the furnace can be represented by post combustion ratio (P CR)

$$\text{PCR} = \frac{\% \text{CO}_2}{\% \text{CO} + \text{CO}_2} \quad (2)$$

Advantages:

- Higher melting rates can be achieved
- Reduced green house gas emission /ton of steel because more scrap can be used

- Reduction in slopping. This is achieved by increase in slag temperature which helps dissolution of lime in slag and decrease in slag viscosity.

Technology of post combustion

A technology is required which can inject oxygen in the converter just above the slag so that CO can be combusted to CO_2 . The supply of oxygen for the post combustion must be well distributed above the slag surface for an efficient combustion of CO. Transfer of the heat to the slag and metal phase is also to be considered.

One possible way is to add several small orifices around the main supersonic nozzle tip. Lance distance has to be adjusted so that oxygen through the orifice is available for combustion of CO to CO_2 above the slag surface.

Still another method could be a lance with double flow for oxygen. In the main oxygen lance, a separate oxygen inlet and oxygen control system can be provided which is solely dedicated to post combustion. This design may provide better control of oxygen for post combustion without affecting the oxygen flow through the main lance.

One of main requirement of oxygen flow for post combustion is that velocity and angle of oxygen flow should be low to avoid the refractory wear. Nozzle diameter, angle of oxygen flow and location of nozzle are the principle design issues.

Potential post combustion issues

- Repair costs of post combustion lance are higher
- Post combustion lances are not rigid as standard oxygen lances.
- Optimization of angle, location, number and diameter of ports for supply of oxygen needs to be established keeping in mind the refractory wear.
- Development of high quality refractory would be required because high temperature would be generated in the post combustion zone.

Slag splashing

Splashing of slag to coat the refractory lining has become a standard practice to increase the lining life. Slag splashing is done as follows:

- At the end of BOS process, steel is drained of and slag is retained in the vessel.

- The O_2 lance is lowered and high pressure N_2 is used to splash molten slag on the walls of BOS vessels for a period of 2 to 4 min.
- Slag refractory provides a consumable refractory lining which protects the furnace lining.
- The excess slag is poured out.

What is required for slag splashing?

- Compositional adjustment of end slag against FeO_x and MgO concentration. Presence of MgO in the end slag should be greater than 13% to produce a high temperature phase and to increase slag viscosity.
- FeO reduces melting temperature of slag and increases the amount of low melting phase in slag. Low melting phase ensures good adhesion between slag and refractory and high melting phase MgO . Fe_2O_3 imparts erosion resistance to the lining.
- Al_2O_3 content of slag should be low
- For $\frac{CaO}{SiO_2}$ ratio greater than 5, SiO_2 should be added

Figure shows schematic diagram of slag splashing in a converter

Figure 14.1: schematic representation of slag splashing in converter

Liquidus Temperature of splashing slag:

The liquidus temperature of slag is important because

- Slag layer should contain enough high temperature phases to prevent attack by slag during BOF process.
- Low melting phase melts and thereby coating thickness decreases
- Too high liquidus temperature will lead to non uniform distribution of slag and there is tendency for the slag to build up at the bottom.

Problems with slag splashing

A. Lance skulling

This is particularly severe if some metal is left in the vessel

- B. Vessel mouth skulling.
- C. Blockage of tuyeres
- D. Sensors are embedded in the refractories to detect the presence of slag during tapping. The slag coating interferes with the detection.

Benefits of slag splashing

- I. Longer life of furnace lining (over 60000 heats).
- II. More recycling of BOF slags.
- III. Less CaO is needed in BOF process due to dissolution of basic slag coating.
- IV. Decrease in sloping results in increase in yield.
- V. Rapid formation of slag occurs due to melting of low temperature phase of the coating.

Slag free tapping

Primary steelmaking slag contains FeO , SiO_2 , P_2O_5 and CaO .

FeO content varies from 15-18 %. These slags are oxidizing in nature. During tapping, carry-over of slag should be avoided for the following reasons:

- During ladle treatment impurities can revert back from slag to metal.
- During synthetic slag practice in ladle, composition of slag will be altered which will affect secondary steelmaking refining operations like desulphurization, deoxidation etc. This will lead to increased consumption of deoxidizers
- Carried-over slag can increase the refractory wear.
- FeO and MnO of slag react with Al and forms Al_2O_3 which is a solid inclusion at the steelmaking temperature, this will affect steel cleanliness.

Mechanism of slag carry-over

Slag can be carried-over from converter to ladle in the initial stage when converter is tilted. As tapping proceeds converter is tilted further which leads to formation of vortex and top slag is carried into the ladle. During up-tilting, part of the slag may be carried into ladle.

The amount of drained slag depends on tilting speed of converter, bath level, drain velocity

Prevention of slag carry-over

Several methods are developed and in use to minimize slag carry-over. Tap-hole plug, slag cut ball pneumatic slag stopper and slag detection methods are commonly in use. The interested reader may look into the references given at the end of the lecture

References

Kenneth. C Mills : A review of slag splashing, ISIJ International, vol. 45 (2005) PP 619-633.

Ghosh : secondary steelmaking.

S C Koria and P Umakanth: Model studies of slag carry-over during drainage of metallurgical vessels , Steel Research 65 (01), 1994, 8-14.

S C Koria and P Umakanth: Water model study of slag carry-over during molten steel transfer, Trans. Ind. Inst. Metals 47 (2-3), 1994, 121-130

R.J.Fruehan: Ladle metallurgy principles and practices

K.W.Lange: Thermodynamics and kinetics of secondary steelmaking processes, Intern. Materials reviews, 1988, P53