L 2 Modern steelmaking

Contents:
Concept
Primary steelmaking
Secondary steelmaking
Continuous casting and thin strip casting
Final finishing operations
Key words: Primary steelmaking, ladle metallurgy, ingot casting, continuous casting

Concept

The concept of modern steelmaking is to make use of the steelmaking vessels like converter, ladle and tundish of a continuous caster. In all these vessels molten steel is handled for one or the other purpose. For examples ladles are used to transfer the molten steel either to ingot casting or continuous casting. Tundish of a continuous caster is used to transfer molten steel to the continuous casting mould. In all these vessels the residence time of molten steel is sufficiently long so as to carry out some refining operations like composition adjustment, removal of gases, control of S, removal of inclusions etc. in ladle and tundish. This has led into the development of ladles, tundishes for some refining operations like deoxidation, inclusion modification, desulphurization etc. and other operations like composition adjustment, inclusion removal etc. The basic idea of employing ladles and tundishes for either refining or composition adjustment or for producing clean steels is to use the steelmaking units like converter and electric furnace for producing steels without much bothering for final chemistry. Modern steelmaking comprises of hot metal / scrap to finished products through the following

a) Primary steelmaking
b) Secondary steelmaking
c) Continuous casting
d) Finishing operations

Primary steelmaking

Primary steelmaking consists of refining of hot metal or scrap +hot metal to steel in a) converter and b) Electric furnace. The objective is to refine hot metal to the nearly desired chemistry.

a) Types of converter steelmaking

- In converter steelmaking pure oxygen is blown from top through a water cooled lance fitted with multi-hole nozzles. This technology of refining of hot metal is called top blown steelmaking.
- In another version of converter steelmaking oxygen is blown from top and bath is gas stirred through the bottom. These are called combined top blowing and bottom stirred processes.
- In some converters, O_2 is blown from top and bottom and these processes are called top and bottom blowing, Duplex blowing or hybrid blowing.
- In some converters oxygen is blown through the bottom and the process is bottom blown converter. This variant is not popular amongst steelmakers

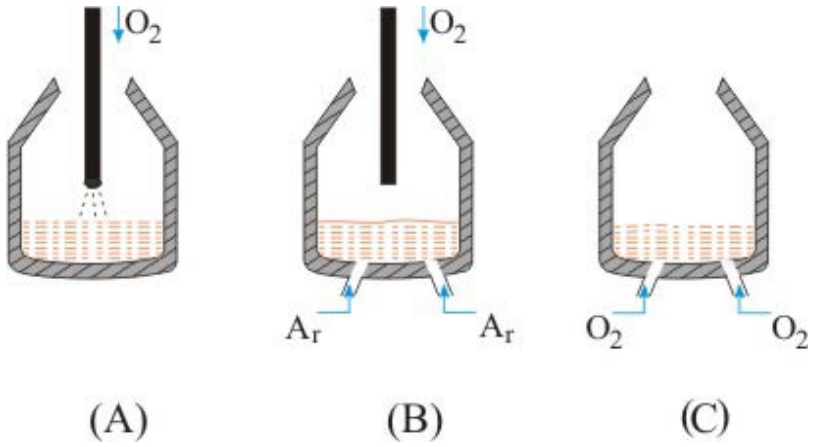

Fig. 2.1 Types of converter steelmaking (a)Top blown steelmaking (b) Combined top and bottom blowing, and (c) Bottom blowing

It is important to note that in all different types of converter steelmaking practices, a pear shaped vessel is used and blast furnace hot metal is refined to plain carbon steel. Some amount of scrap is also used.

Principle chemical reactions

Hot metal contains C ~ 3.5 to 4%, Si ~ 0.6 to 1%, Mn~ 0.6 to 0.8% and P ~ 0.1 to 0.2%. Oxygen is blown from top and the following reactions occur:

$$[Fe] + [O] = (FeO) \quad (1)$$

$$[C] + [O] = \{CO\} \quad (2)$$

$$[Si] + 2[O] = (SiO_2) \quad (3)$$

$$[Mn] + [O] = (MnO) \quad (4)$$

$$2[P] + 5[O] = (P_2O_5) \quad (5)$$

$$[C] + (FeO) = \{CO\} + [Fe] \quad (6)$$

$$(Fe) + (MnO) = (FeO) + [Mn] \quad (7)$$

Note the following:

- No heat is supplied from outside. The heat produced due to chemical reactions is sufficient enough to raise the temperature of hot metal from around 1250℃ to 1300℃ to molten steel tapping temperature of 1600℃ to1650℃ .
- Except carbon which is removed as a gaseous phase rest all other elements form slag. Slag formation of desired chemistry and physico-chemical properties is vital for the successful operation of converter steelmaking technology.

- Typically converter steelmaking technology allows to tap liquid steel in approximately every 50 to 60 minutes with specified steel chemistry and 500-1000ppm dissolved oxygen.
- Typically oxygen blowing time is independent of converter capacity i.e. O_2 is blown for 15 to 20 minutes irrespective of the converter capacity.

b Electric Arc furnace (E A F)

In electric arc furnace steelmaking scrap + hot metal + directly reduced iron is used to produce plain carbon steel

Electric energy is the principle source of thermal energy. Graphite electrodes are used to supply the current (see figure 2.2). The AC electric arc furnaces are very popular. EAF can be either normal power or ultra high power (UHP) with single or twin shell, with or without bottom stirring or post combustion. EAF generates a considerable noise. Now a days EAF has occupied a unique position in the steel industry: EAF can be switched over easily to produce plain C or alloy steel depending on the market requirements.

Figure 2.2: Electric arc furnace

Secondary steelmaking

The objective of secondary steelmaking is to make the steel of desired chemistry and cleanliness by performing the following treatments in "Ladle":

a) To stir the molten steel by purging inert gas through the bottom of the ladle.
b) To inject slag forming powder either through a lance for further refining
c) To produce clean steel either by removing inclusions or modify them by suitable injecting materials
d) To carry-out deoxidation and degassing.

Secondary steelmaking in ladles has become an integral part of steelmaking. Ladles have additional heating facility and are called Ladle furnaces (LF).

There are several practices adopted for degassing, like vacuum tank degasser, stream degassing and recirculation degassing. In recirculation degassing steel is made to flow from the ladle into a separate degassing chamber and then returned after exposure to the vacuum. In one of the recirculation degassing practice metal circulation is achieved by dipping the degassing vessel into the ladle, the liquid steel is raised into the vessel, degassed and returned into the ladle.

In another practice a refractory lined vessel is equipped with two legs (called snorkels) for dipping into the ladle containing molten steel. Pressure is reduced and argon gas is passed into one of the snorkel, thereby molten steel is raised into the vessel and recirculates back into the ladle through the other snorkel.

Continuous casting and strip casting

Molten steel is being cast continuously in to billets, blooms and slabs depending on the desired product i.e. whether long or flat products. In continuous casting, tundish, mold and secondary cooling sprays are arranged such that steel is poured continuously from the tundish and the solidified cast product is withdrawn continuously.

The arrangement of the tundish, mold and spray is shown in the figure 2.3.

Figure2.3: continuous casting process.

The original continuous casting machines were of vertical types. Now most of the continuous casters have either curved mould (Figure 2.3a) or vertical mold with bending rolls.

In the continuous casting, tundish is the important refractory lined vessel. It feeds the molten steel into the molds placed beneath the tundish through a submerged nozzle. Tundish also acts as reservoir of molten steel during ladle change-over periods and sequence casting. Modern tundishes are equipped with furniture like dams, weirs, slotted dams etc. to modify the molten steel flowing in the tundish during the process of continuous casting. Modern developments include thin slab caster, liquid core reduction. Thin slab casters are connected to the strip mill. The objective is to integrate the casting and rolling in order to save reheating cost.

Strip casting is (Figure 2.3b)also becoming popular in steel plants. Here molten steel is cast directly into the strip.

Final finishing operations:

It has been considered appropriate to include final finishing operations in steelmaking course to appreciate integration between chemistry and cleanliness of steel and the final finishing operations. It is thought that the reader can appreciate the role of steelmaking in the product development and failure. The following finishing operations are dealt with

- Deformation processing technologies like forging rolling etc.
- Heat treatment to produce the finished product. Heat treatment consists of heating the steel products to a temperature in the austenitic region and then cooling.
- Surface hardening treatment

References:

A. Chakrabarti: Steel making