Lecture 34 Advances in Continuous Casting of Steel

Contents

Key words: Thin slab casting, strip casting, Hot rolling, direct charging

Introduction

Continuous casting is one of the most significant developments in the technology of steelmaking. A ladle containing 300 tons of molten steel at 1600 can be cast into approximately 60 minutes in a semi-finished product like bloom, billet and slab. It reduces energy consumption, material handling and as a result lead to increase in plant productivity. In addition continuous casting offers the possibility to integrate the hot strip or blooming mill by direct hot charging. In recent years considerable developments have taken place both in conventional continuous casting to improve the product quality and to develop new technology to produce nearly finished products. Some of the developments are briefly described.

Electromagnetic Stirring(EMS)

EMS is an electric method of inducing motion in liquid steel without using any mechanical device. In continuous casting EMS can be applied in mold and secondary cooling zone to

- Decrease segregation and porosity
- Improve steel cleanliness by forcing inclusions to float on the surface where they can be absorbed by a slag
- Improve the steel quality in terms of reducing the defects

Stirring induced by EMS modifies the flow pattern of molten steel of the solidifying strand. Improved stirring reduces segregation. Because of the imposed stirring, the superheat of the melt can be quickly dissipated which results in modification of structure of the solidifying strand from columnar to equiaxed and then to globular structure.

EMS allows to increase the casting speed which increases productivity of the caster.

An inductive electromagnetic stirrer is the stator of an asynchronomous motor, the rotor of which is the liquid core of the solidifying strand. This stator produces either a rotating or travelling magnetic field B, which induces eddy current J, perpendicular to B and its velocity vector. B and J combine together to create an electromagnetic force which causes stirring in the bath. The mains frequency is usually used for stirring billets or small blooms beneath the mold . In secondary cooling zone low frequency (1 to 20Hz0 is required to electromagnetically stir the liquid steel of the solidifying strand because the thick solid steel shell shields the magnetic flux.

High speed Casting

High speed casting of slab increases the productivity. Average casting speed in the conventional slab casters is on average 2 m/min. Now if want to increase the casting speed we have to consider design and operational features of tundish, mold and secondary cooling zone. This is illustrated by the following example;

Consider a conventional 2 strand caster casting slab of cross section 280mm x 1950mm at 2 m/min casting speed. Molten steel is fed from a tundish of 70 tons capacity by submerged entry nozzles in both the molds of the continuous casting machine.

Volume of slab /minute = 1.092 m^3/minute. Assuming density of liquid steel as 7 tons/m^3 steel flow rate is 7.6 tons/minute/strand.

Now if we increase casting speed to 3 m/min., the required steel flow rate would be 11.4 ton/min/strand, and which will increase to 15.2 tons/min/strand for 4 m/min casting speed. Now let us calculate the average residence time of molten steel flowing in the tundish assuming 70 tons tundish will be used even for high speed casting

Steel flow rate (tons/min/strand	Residence time (minutes)
7.6	4.6
11.4	3.1
15.2	2.3

We note that the average residence time of steel melt in the tundish decreases with the increase in the casting speed. Thus, chances of inclusion floatation will be very low at higher casting speeds. Thus, the following modifications may be considered;

In one modification tundish capacity needs to be increased, if tundish is to be used to remove inclusions during the process of continuous casting. Thus, a change in tundish design would be required. In other modification we improve the upstream steelmaking facility so that inclusion content in steel are within the tolerance limit. One may consider other alternatives depending on the available resources.

We have to consider further as to what will happen in the mold? Increase in steel flow rate will increase the steel velocity in the mould since the mold length is not being changed. One requires to consider the cross section of the submerged entry nozzle too. The higher steel flow rate in the mold would require intense cooling in the mold. The steel flow in the mold will be more turbulent. Also the mold powder consumption may increase. We would be requiring mold flux whose melting rate is relatively higher to keep pace with the casting speed.

Similarly water spray in the secondary cooling zone has to be modified in view of the increase in the casting speed. Uniform cooling of the strand is the prerequisite for the success of the caster.

Thin Slab Casting

Thin slab casting aims at to cast slabs of thicknesses less than 100 mm, say around 60 to 80 mm. The objective is to integrate caster, reheating furnace and hot strip mill to increase the productivity. A slab of cross section 1500mm x 80mm would require melt flow rate 3.78 tons/min at 4.5 m/min casting speed. Since the mould size is smaller turbulence in the mould increases which results in entrapment of mould flux on surface causing surface defects.

Use of funnel shaped mould with enlarged cross section at the meniscus is one remedy. Electro-magnetic brakes are very effective in parallel moulds.

Development of liquid core reduction is one such technology that has helped thin slab casting development. Solid ingot with liquid core is subjected to on-line rolling. This brings the following advantages;

- Rolling can be eliminated
- Improved internal quality in term of segregation

Thin slab caster can be integrated with EAF units and hence mini steel plants are using thin slab casting to produce hot strips with lower segregation, finer grain size and higher strength

Near Net shape casting

The conventional methods of producing metallic strips and sheets require the casting of large ingots which are subsequently hot rolled and cold rolled to final thickness. Several unit operations like ingot soaking, slabbing mill, intermediate annealing, pickling are required to produce the strips. An alternate to this route is the near net shape casting or direct strip casting. In this technology strips are cast close to the final desired thickness and thus many of the unit operations in the conventional technology can be eliminated.

The near net shape casting units are classified into four categories, namely

I. Thin slab caster producing 20mm to 70mm thick slabs of cross section 20mm to70mm X 1000mm to 2000mm which could be fed directly into the finishing stands of the hot strip mill without any conditioning

II. The thick strp caster producing 10mm to 20mm thick strips which may need some limited rolling for metallurgical reasons.

III. Strip casters producing strips less than 10mm thickness which is sent directly to the cold strip mill

IV. The thin strip or foil caster with a thickness of approximately 20μm to 500µm thickness and upto 300 mm wide.

Several technologies are developed for the above casters. In the technology developed by Mannesman demag Huettentechnik thin slab of 40mm to 70mm thickness and 1200 mm width can be produced. The features are;

- A narrow submerged nozzle
- Vertically curved mould with parallel broad faces that guide the strand vertically
- Adjustable mould width
- Dry casting technique

In addition there are twin roll caster, drum and ring caster, sinfle roll caster, rheocaster and powder rolling caster. Details can be seen in the references given at the end of the lecture.

Mist Spray Cooling

In mist spray , cooling is provided by a mist which is a two phase mixture of air and water; water droplets are finely distributed in the air jet. Air in which fine water droplets are distributed is blown on to the casting section; the water disperses on the casting section surface in the form of a mist. The mist spray provides uniform cooling. For the mist, control of volume flow rate of air to volume flow rate of water and upstream pressure must be suitably selected. The condition of the mist stream is strongly affected by the design of the nozzle

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