Recent Trend on Tundish Design

M.R.Sadual*, S.K.Swain, M.Kumar
Department of Metallurgical & Materials Engineering
National Institute of Technology, Rourkela, Odisha-769008, India
*Corresponding Author, Email: mrsadual@gmail.com

Abstract

Approximately 90 % of world's crude steel production is casted using a continuous casting process where the liquid steel flows from ladle to tundish next to mold in a continuous casting system. In modern steelmaking and continuous casting plants, tundish technology from both fundamental and practical point of view is most important. Steel is produced in three basic route like, basic oxygen furnace (BOF), electric arc furnace (EAF) & induction furnace (IF). BOF hot metal and scrap are blown by oxygen gas with a flux addition such as lime etc. A modern EAF produces steel by remelting and refining steel from DRI, scrap and other raw materials, and also uses oxygen gas injection and lime addition. In induction furnace main input raw materials are DRI & scrap.The steel melt with dissolved oxygen thus produced is tapped into a ladle, where it is deoxidized with ferroalloys, Fe-Si, Fe-Si-Mn, and/or metallic aluminum. The deoxidation products,such as silica, manganosilicates, alumina, aluminosilicates, aluminates and/or their composites, are largely removed from the melt by flotation.Whenever necessary, the deoxidized melt is further processed in a ladle furnace (LF) to remove any remaining suspended oxide particles (called non-metallic inclusions, or simply inclusions), to lower the sulfur content, and to adjust the melt's chemistry and temperature. Degassing of steel melt is done in vacuum refining facilities (RH, VAD, or VOD) to decrease hydrogen for crack sensitive grades and/or carbon for ultra low carbon grades. The melt is then transferred from the ladle via a tundish into the mold of a continuous casting machine and is solidified as slabs, blooms, or billets. In the last three decades, continuous casting has become a mature technology for the solidification of steel. Continuous casting offers many advantages including better premium cast-metal yield chemical homogeneity, and better inclusion cleanliness. In continuous casting process, the tundish plays an important role in linking the ladle with the continuous casting machine. Tundish technology as an important component of the steel production processes, with emphasis placed on the metallurgical aspects of producing clean steel.

The present paper reviews the Tundish design requirement based on survey in different journal, literature & from author’s working experience. Role of Tundish, basic feature with Tundish, thermal states of tundish during continuous casting, flow dynamics with tundish are highlighted in this paper.

Keywords: Steelmaking, Tundish, Liquid Steel, thermal states, Flow simulation, Heat loss

1. Introduction

1.1 Role of Tundish in the Continuous Casting Process

To transfer finished steel melt from a ladle to the mold in a continuous casting machine, an intermediate vessel, called a tundish, is used. The tundish is intended to deliver the molten metal to the molds evenly and at a designed throughput rate and temperature without causing contamination by inclusions. The tundish acts as a reservoir during the ladle change periods and continues to supply steel melt to the mold when incoming melt is stopped, making sequential casting by a number of ladles possible. The main causes for inclusion formation and contamination of the melt include reoxidation of the melt by air and carried over oxidizing ladle slag, entrainment of tundish and ladle slag, and emulsification of these slags into the melt. These inclusions should be floated out of the melt during its flow through the tundish before being teemed into the mold. Without LF processing, the deoxidized melt had macro inclusions and a large number of micro inclusions of indigenous origin that could agglomerate to form macro inclusions during the melt transfer. A tundish was able to reduce some fraction of macro inclusions from the melt, adjust chemical compositions, and control melt temperature to an appropriate level for feeding into the mold. With the use of the LF and/or degasser, melt cleanliness has significantly improved and the tundish is now seen more as a contaminator than a refiner. Appreciable contamination generally occurred during transient periods (or non steady state) of the sequential casting, i.e., during ladle opening, at the transition of two heats (or ladle change), and during ladle emptying, during transient periods, the incoming melt stream and any metal splash are heavily reoxidized by the ambient air and by the oxidizing ladle slag that is carried over into the tundish with the melt.

The melt stream hits and aggressively emulsifies the ladle slag and tundish slag floating on the melt surface, which eventually get entrained into the melt. Both the reoxidation and the slag entrainment generate harmful macro oxide inclusions. The Al-deoxidized steel melt, even after removal of large particles of deoxidation product in the LF, contains a large number of suspended fine alumina particles. These particles were found to agglomerate by turbulent melt flow during the melt transfer from the ladle via the tundish to the mold, forming large alumina clusters. The macro inclusions and large alumina clusters are known to be the major cause of downstream processing problems and defects occurring in strands and their final products. Design and operation of a tundish must be directed toward minimizing the formation of the macro inclusions and alumina clusters, and removing them once they form. Otherwise, all the effort made in cleaning the melt in the LF and during other process steps would be of no value. Various technologies such as a long nozzle or an inert gas shrouding pipe have been implemented to reduce air reoxidation and slag emulsification. Similarly, melt flow control devices have been used to enhance flotation of inclusions formedduring the process. Implementation of active control of the melt temperature in a tundish has also contributed to casting clean steel. These measures have proved to be quite successful, at least during the steady state tundish operation, but may not be sufficient for the non-steady state operation, Non-steady state operation is an integral part of long sequential casting for better metal yield. Although it is desirable to cast steel of high quality, a compromise between the quality and cost has always been struck in any tundish operation.

2. Feature with the Tundish

A tundish, as shown in Fig-3 & 4 big-end-up, refractory-lined vessel, which may have a refractory-lined lid on the top. The tundish bottom has one or more nozzle port(s) with slide gate(s) or stopper rod(s) for controlling the metal flow. The vessel is often divided into two sections an inlet section, which generally has a pour box and where steel melt is fed from the ladle; and an outlet section from which melt is fed into the mold(s). Various flow control devices, such as dams, weirs, baffles with holes, etc., may be arranged along the length of the tundish. The elevation view of different tundish shapes is shown Fig. 3 & 4 indicate melt path from inlet to outlet of the tundish. Longer path is preferred to prolong melt residence time to promote flotation of macro inclusions. The number of molds is usually 1 or 2 for a slab caster, 2 to 4 for a bloom caster, and 4 to 8 for a billet caster. The melt delivery rate into the mold is held constant by keeping the melt depth in the tundish constant. Any additional delivery rate control is exerted by the slide gates or stopper rods placed at the exit ports of the outlet compartment.

3. Thermal states of Tundish during continuous casting

The knowledge of the temperature of steel poured from the ladle is relevant to obtain high quality products. High superheat above liquidus temperature in the tundish will increase central segregation, affect grain size and even produce breakouts owing to local solidified shell thinning of cast products, interrupting the continuous casting sequence. On the other hand low super heat in the Tundish will promote clogging of tundish nozzles, macro inclusions entrapment and will affect flux powder melting increases the probability of mold sticker formation.

After tapping from the BOF/ EAF the liquid steel held in the ladle is transferred to the ladle, Furnace and Trimming station, for final grade composition and temperature adjustment. Then the ladle is delivered to continuous caster and no further temperature correction is possible. Thus the forecast of steel temperature to be poured in the tundish depends upon many operating parameters such as the thermal history and wear of the tundish refractory lining , precise knowledge of refractory thermal properties and transfer coefficients, the use of tundish covers and insulating slag layers , the time of each operating stage lasts, teeming rate.

4. Flow dynamics with Tundish

Earlier days water modeling was the tool to determine the flow dynamics with the tundish. After development of computational modeling now it become a powerful tool for the analysis flow dynamics as well heat losses of liquid steel along the continuous casting process. Numerical fluid dynamics is the fundamental which is intensively applied to analyze the characteristics of the fluid flow in the tundish for design optimization. Physical modeling of transport phenomena has also assisted in the understanding of fluid flow in steel casting vessels in general. Tundish thermal state during continuous casting as function of heat losses through the tundish shell, insulation of the steel bath and temperature.

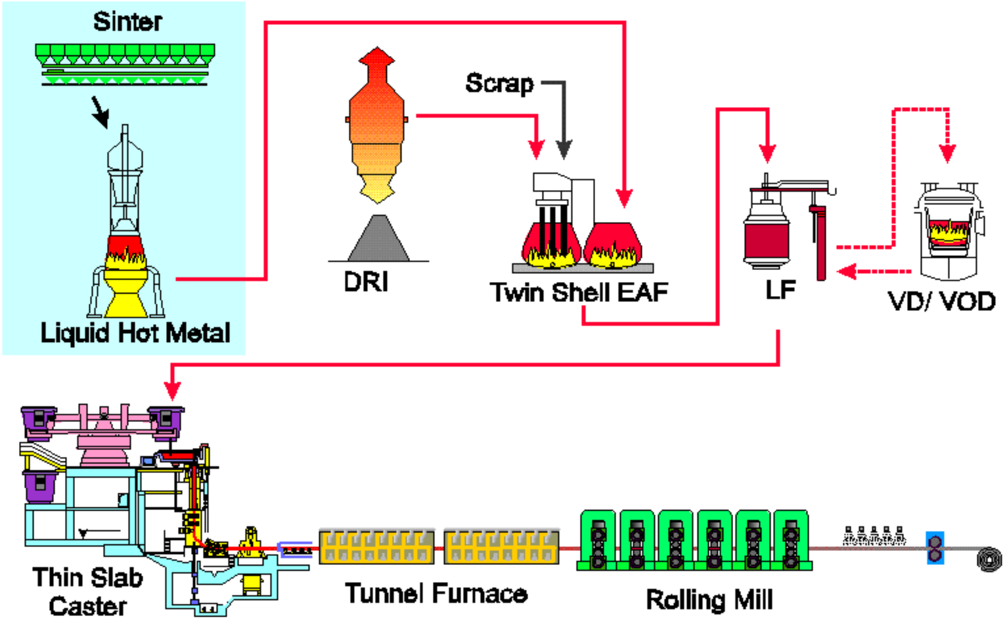

Figure 1. Schematic view of a steel plant

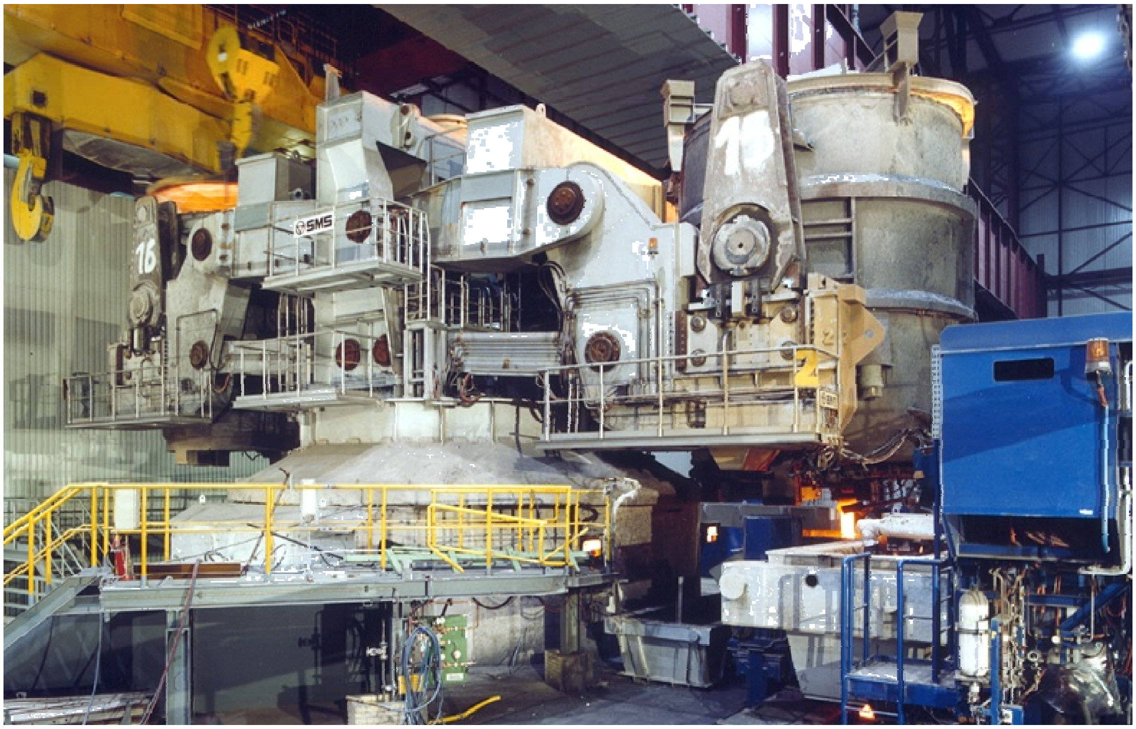

Figure 2. Photograph of a continuous casting shop

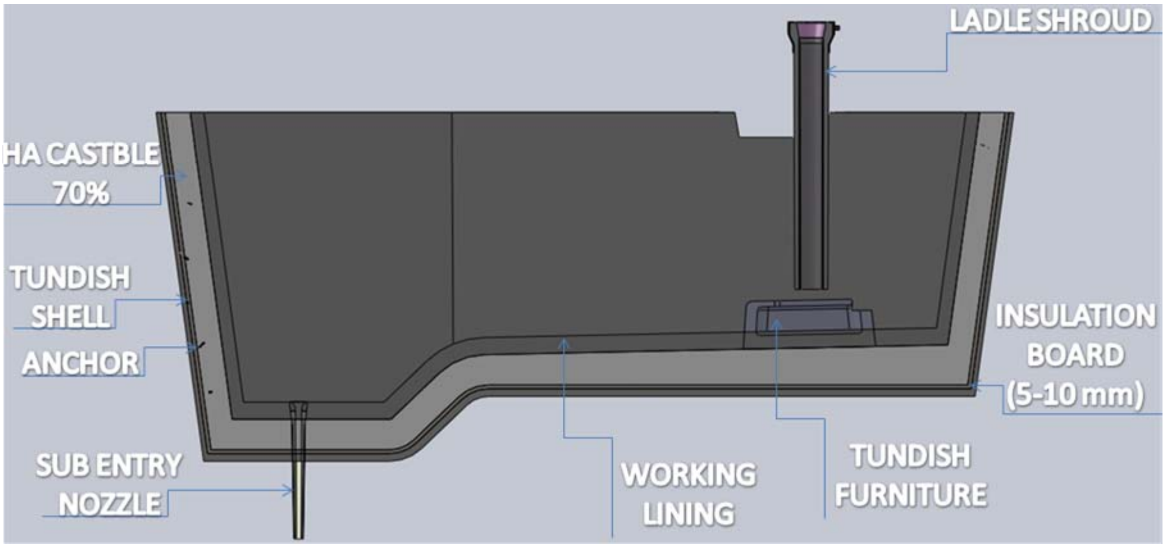

Figure 3.Schematic view of a Tundish

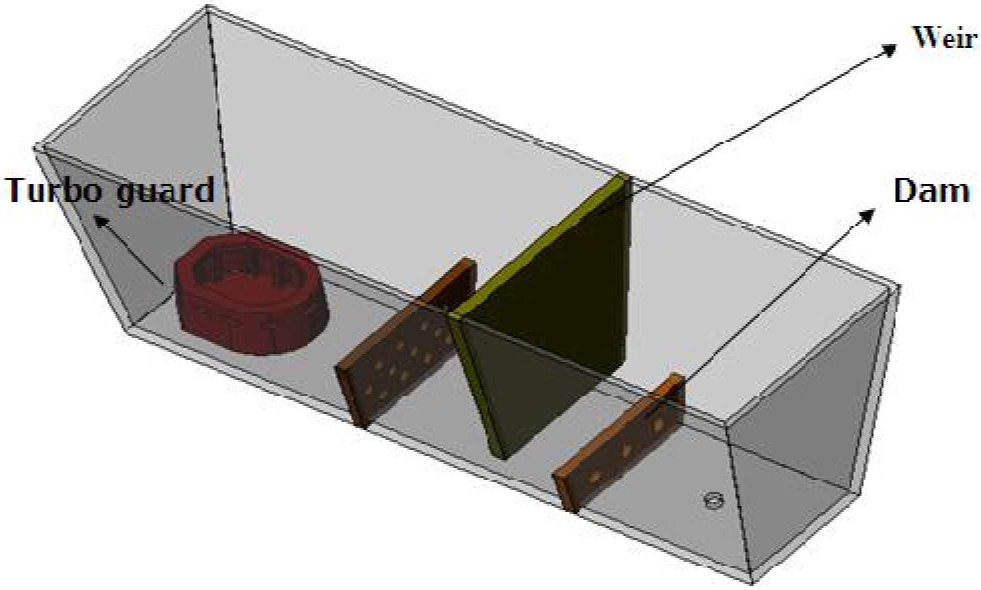

Figure 4.Schematic view of Tundish

5. Conclusions:

The following conclusions have been made:

(a) The tundish is intended to deliver the molten metal to the molds evenly and at a designed throughput rate and temperature without causing contamination by inclusions.

(b) A tundish was able to reduce some fraction of macro inclusions from the melt, adjust chemical compositions, and control melt temperature to an appropriate level for feeding into the mold.

(c) Various technologies such as a long nozzle or an inert gas shrouding pipe have been implemented to reduce air reoxidation and slag emulsification.

(d) The melt delivery rate into the mold is held constant by keeping the melt depth in the tundish constant. Any additional delivery rate control is exerted by the slide gates or stopper rods placed at the exit ports of the outlet compartment (Fig. 3 & 4).

(e) The forecast of steel temperature to be poured in the tundish depends upon many operating parameters such as the thermal history and wear of the tundish refractory lining , precise knowledge of refractory thermal properties and transfer coefficients, the use of tundish covers and insulating slag layers , the time of each operating stage lasts, teeming rate.

(f) Tundish thermal state during continuous casting as function of heat losses through the tundish shell, insulation of the steel bath and temperature.

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