Thermal Analysis of Tundish in Continuous Casting Machine in Steel Industry

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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). In BOF hot metal and scrap are blown by oxygen gas with a flux addition such as lime etc. The aim of this project is to minimize the slag layer developing during the casting sequence and to improve the performance of M.B.S. and Tundish also. For that one Tundish model made to experiment and same result check by means of ANSYS analysis and also analytical result of Tundish heat loss verified.***

Key Words: *Continuous Casting Tundish, Mono Block Stopper, ANSYS, Sub Entry Nozzle*

1. INTRODUCTION

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.

As per stated worlds 90% of crude steel produce by means of continuous casting. so it is important to mention that caster plays an important role in steel production because if somewhat reason may any defect in casted slab occurs that defect also continuously goes in consequently occurring processes such as Hot Rolling process which produces Hot rolled coil, Hot rolled plate and also can pass further in Cold rolling process which produces galvanized thin sheet, corrugated sheet, Chequred sheet, Steel strip. Another major problem identified in our UVSL caster Tundish that, there is open surface from some point over Tundish. Because due to slag and metal, upper surface of metal getting solid and stick to flow regulating stopper called as Mono Block Stopper and it is much harmful to casting. To remove that sticking during casting one man continuously climbs over and remove that slag formation my means of lancing pipe and it is much more hazardous.

The present work focused on investigation and minimization of slag formation around the Mono Block Stopper (M.B.S.). The main objective of this project is to evaluate the performance of the Tundish used in UVSL through application of Air Nozzles around the M.B.S. so as restriction of slag-metal formation over Mono Block Stopper in Tundish.

2. EXPERIMENTAL SETUP

Here for experimentation we used Tundish used in UVSL by which we getting pick up data related to temperature and other actual dimensions which we required for our analysis and on the other hand we had made one experimentation small model Tundish for analyzing the slag removing phenomenon by application of air. So here we have taken in consideration both models for our Experiment. Actual setup Tundish we used for our experimentation is Tundish used in UVSL. This Tundish made to regulate the flow of around 1600˚C. The Tundish outer& inner shell is basically made up of mild steel. The internal part of Tundish getting covered with anchor clip, which help to stick the permanent refractory lining. Over anchor clip permanent refractory lining getting patching which form the internal surface for metal flow. And finally we made spray mass coating over permanent lining and that coating us getting covered over it after every sequence. For our experimentation we consider two cases of Tundish by which metal slag removal have to analyze:

2.1.1 Case-I: In this case we had simply analyzed the metal slag formation at upper surface of Tundish and subsequent its effects on Mono Block Stopper (M.B.S.) such as sticking, it getting analyzed in Tundish used in UVSL.

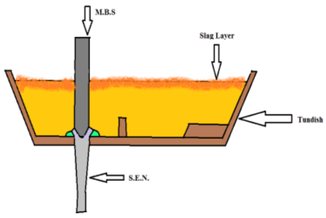


Fig 2.1.1- Case-I

2.1.2 Case-II: In this case we had made some arrangement in Tundish it includes introduction of air nozzle around the Mono Block Stopper (M.B.S.) by means of which metal slag formation can be removed and getting better performance of Tundish.

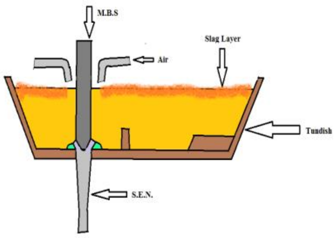


Fig 2.1.2- Case-II

2.2 Experimental Model Tundish Setup used

In this experiment we made one model Tundish, which too much small as compared to the actual Tundish we considered. By means of this model Tundish we are getting experimentation on slag removal technic by application of air. This model Tundish shell is also made up of mild steel. In this model we placed one rod at one side of Tundish which act as mono block stopper (M.B.S.) in this model. At one side of this nominated M.B.S. one nozzle is fitted for air flow. To regulate the air flow air nozzle is also provided. Intermediate the valve and regulator there is pressure gauge is provided to set the predetermined value. Air compressor is also required for the air. In this model Tundish experimentation we use liquid aluminum as a flow material.

2.3 Experimental Procedure

Experimentation is conducted on model Tundish to determine its performance while slag formation. In this experiment we use liquid aluminum in place of liquid metal because liquid M.S. in normal condition difficult to melt without advanced furnace but aluminum can be melt with some hand blower arrangement. The procedure used in experiment is described as follows:

- Model Tundish place some flat surface and air compressor getting connected to it.
- Melt scrap aluminum piece into liquid aluminum by means of hand blower operated small furnace.
- Pour liquid aluminum into the model Tundish.
- Allow air to flow through nozzle over the nominated M.B.S.
- Check whether the air impacting sufficient for ring formation around the M.B.S. if not then increase the air intensity by means of regulating valve.

3. EXPERIMENTAL RESULT

As we discuss earlier chapter that experimentation readings takes directly from Tundish used in UVSL and from which some sample calculation made to show our experimentation result.

3.1 Analytical Calculation

Tundish Length (L) = 3.804m

Tundish Width (W) = 1.060m

t_{slag} = 800˚C

t_{Cover} = 500˚C

Temperature of Surrounding (t_{∞}) = 36˚C

Density of Steel (ρ) = 7.85 Kg/m^3 -- {from Data Book P.NO.1}

Thermal Diffusivity (α) = 17.70$\times 10^{-6}$ m^2/s -- {from Data Book P.NO.1}

Specific Heat (C_p) = 434 J/Kg-k -- {from Data Book P.NO.1}

$= 434\times\frac{10^{-3}}{273}$

$(C_p) = 1.5897\times10^{-3}$ KJ/Kg°C

Thermal Conductivity (k) = 31.2 W/mk - {from Data Book P.NO.6 t_{Slag} = 800°C}

= 31.2×0.86 kcal/mhr°C

=26.83kcal/mhr°C

= 26.83×4.184 kJ/mhr°C

k = 112.25 kJ/mhr°C

Thermal Conductivity (k) = 38.1 W/mk -- {from Data Book P.NO.6 t_{Slag}=500°C}

= 38.1×0.86 kcal/mhr°C

= 32.766 kcal/mhr°C

= 32.766×4.184 kJ/mhr°C

k = 137.09 kJ/mhr°C

3.1.1 Case-I: When Tundish Open in Atmosphere

Heat Loss by free convection (Q)

μ = ρ × v

$= 7.85\times(17.70\times10^{-6}\times3600)$

μ= 0.50kg/mh

$\beta = \frac{1}{T}$

$= \frac{1}{273+\frac{800+36}{2}}$

$\beta = 0.00144\ k^{-1}$

$G_r = \frac{L^3 g\beta\Delta t}{v^2}$ ---------------- {from Data Book P.NO.135}

$G_r = \frac{3.804^3\times9.81\times0.00144\times(800-36)}{[17.70\times10^{-6}]^2}$

$G_r = 1.8962\times10^{12}$

$P_r = \frac{\mu C_p}{k}$

$= \frac{0.50\times1.5897\times10^{-3}}{112.25}$

$P_r = 7.0810\times10^{-6}$

$G_r\times P_r = 1.8962\times10^{12}\times7.0810\times10^{-6}$

$G_r\times P_r = 13.4269\times10^{6}$

From Data Book P.NO.137, when upper surface cooled or lower surface heated, constant wall temperature, When$(10^5 < G_r\times P_r < 10^{11})$

$N_u = 0.27\times\times(G_r\times P_r)^{0.25}$

$= 0.27\times(13.4269\times10^{6})^{0.25}$

$N_u = 16.3439$

$N_u = \frac{hL}{k}$

$16.3439 = \frac{hL}{k}$

$h = \frac{k}{L}\times16.3439$

$h = \frac{112.25}{3.804}\times16.3439$

h =482.28 kJ/hm°C

Rate of Heat Loss (Q) When Tundish Open in Atmosphere

$Q = h\times A\,(t_{slag} - t_{\infty})$

Q = 482.28× (3.804×1.060) × (800-36)

$\mathbf{Q_{Tundish\ Open} = 1.4857\times10^{6}}$ **kJ/hr.**

3.1.2 Case-II: When Tundish Cover

Heat Loss by free convection (Q)

μ = ρ × v

$= 7.85\times(17.70\times10^{-6}\times3600)$

μ= 0.50kg/mh

$\beta = \frac{1}{T}$

$= \frac{1}{273+\frac{500+36}{2}}$

$\beta = 0.00184\ k^{-1}$

$G_r = \frac{L^3 g\beta\Delta t}{v^2}$ ---------------- {from Data Book P.NO.135}

$$G_r = \frac{3.804^3 \times 9.81 \times 0.00184 \times (500-36)}{[17.70\times10^{-6}]^2}$$

$$G_r = 1.4715\times10^{12}$$

$$P_r = \frac{\mu C_p}{k}$$

$$= \frac{0.50 \times 1.5897 \times 10^{-3}}{137.09}$$

$$P_r = 5.7980\times10^{-6}$$

$$G_r\times P_r = 1.4715\times10^{12} \times 5.7980 \times 10^{-6}$$

$$G_r\times P_r = 8.5317\times 10^{6}$$

From Data Book P.NO.137, when upper surface cooled or lower surface heated, constant wall temperature, When$(10^5 < G_r \times P_r < 10^{11})$

$$N_u = 0.27 \times (G_r \times P_r)^{0.25}$$

$$= 0.27 \times (8.5317 \times 10^6)^{0.25}$$

$$N_u = 14.5922$$

$$N_u = \frac{hL}{k}$$

$$14.5922 = \frac{hL}{k}$$

$$h = \frac{k}{L} \times 14.5922$$

$$h = \frac{137.09}{3.804} \times 14.5922$$

h =525.88 kJ/hm˚C

Rate of Heat Loss (Q) When Tundish Cover

$$Q = h\times A\ (t_{Cover} - t_\infty)$$

Q = 525.88× (3.804×1.060) × (500-36)

Since, $Q_{Tundish\ Open} = 1.4857\times10^6$ kJ/hr.

$Q_{Tundish\ Cover} = 9.8390\times10^5$ kJ/hr.

$\mathbf{Q_{Tundish\ Cover} = 9.8390\times10^5}$ **kJ/hr.**

$$\boxed{Q_{Tundish\ Open} > Q_{Tundish\ Cover}}$$

Therefore,

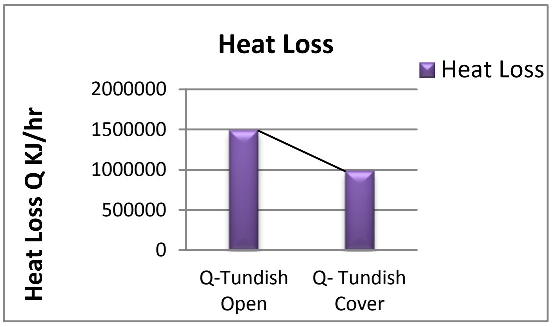
From the above calculation it is calculated that, heat lost by Tundish without cover is more than Tundish with cover.

Therefore,

$$Percent\ Heat\ Loss\ Reduce = \frac{Q_{Tundish\ Open} - Q_{Tundish\ Cover}}{Q_{Tundish\ Open}}$$

$$= \frac{1.4857 \times 10^6 - 9.8390 \times 10^5}{1.4857 \times 10^6} \times 100$$

Percent Heat Loss Reduce = 33.77%



Graph 3.1- Percent Heat Loss Reduce

3.2 ANSYS Analysis Report

3.2.1 Thermal Analysis of Tundish with Heat Flux

[A] Case-I

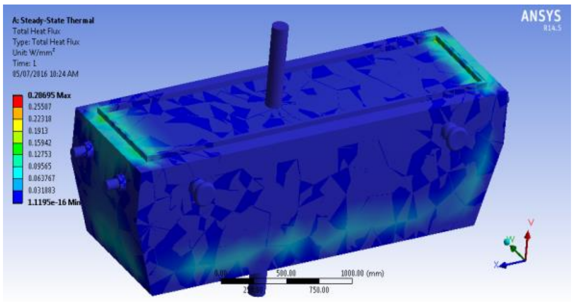


Fig 3.2.1 [A] - Thermal Analysis of Tundish with Heat Flux (Case-I)

[B] Case-II

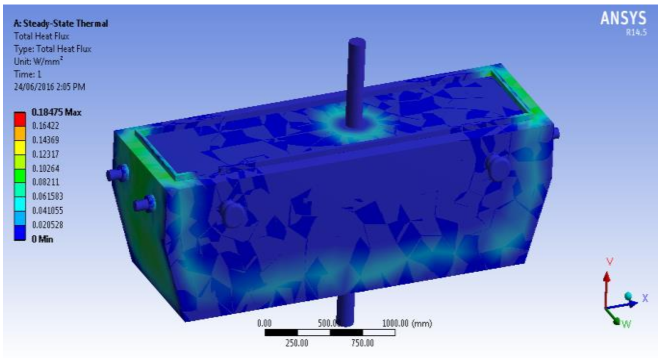


Fig 3.2.2 [B] - Thermal Analysis of Tundish with Heat Flux (Case-II)

3.2.2 Thermal Analysis of Tundish with Temperature

[A] Case-I

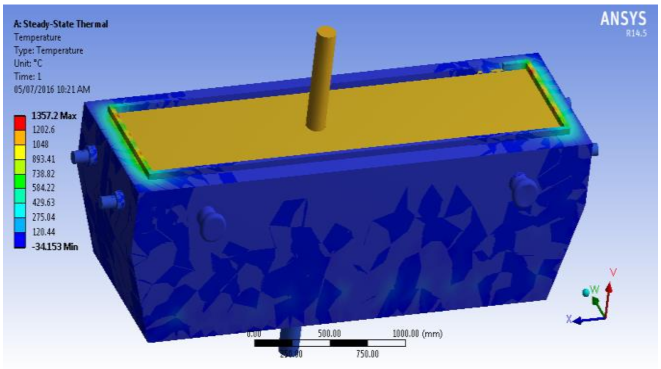


Fig 3.2.2 [A] - Thermal Analysis of Tundish with Temperature (Case-I)

[B] Case-II

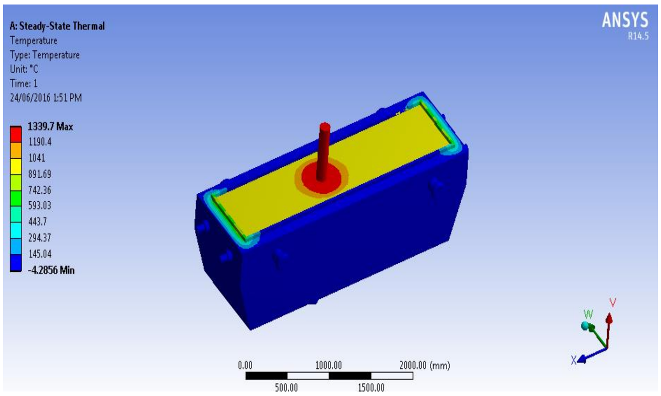


Fig 3.2.2 [B] - Thermal Analysis of Tundish with Temperature (Case-II)

3.2.3 Temperature increased around M.B.S.

t_{Slag} = 800˚C

$t_{After\ Air\ Impact}$ = 1300˚C

Therefore, Percent Temperature increased around M.B.S.

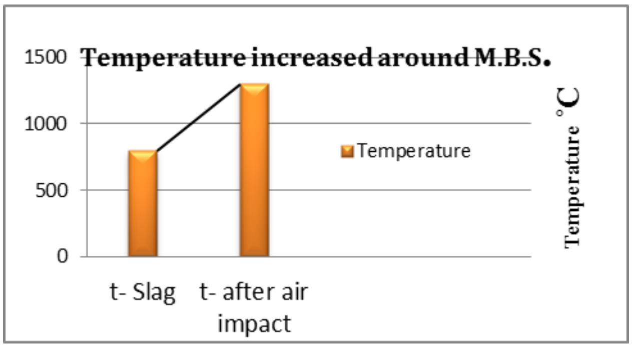
Percent Temperature increased

$$= \frac{t_{After\ Air\ Impact} - t_{Slag}}{t_{After\ Air\ Impact}}$$

$$= \frac{1300 - 800}{1300} \times 100$$

= 38.46 %

Percent Temperature increased around M.B.S. = 38.46 %



Graph 3.2.3- Temperature increased around M.B.S.

4. CONCLUSION

Experimental investigation has been carried out over Tundish and some experimental heat loss and temperature increment calculation has been made to show results then some conclusions have made as follows:

1. Heat lost when Tundish is open to environment getting as
   $Q_{Tundish\ Open}$ = 1.4857×10^6 kJ/hr.

2. Heat lost when Tundish getting closed by means of cover as
   $Q_{Tundish\ Cover}$ = 9.8390×10^5 kJ/hr.

3. From the above calculation it is showing that, percent heat lost from Tundish reduces by 33.77%.

4. Temperature around M.B.S. in normal condition is 800˚C, but after air impact temperature raises up to 1300˚C by ANSYS analysis and it shows that percent temperature increases to 38.46%

From the above investigation by ANSYS analysis it is proved that by application of air around M.B.S. jam removal can be possible

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