Improvement In Ladle Technology For Conservation Of Heat Energy

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***Abstract* — The principal goals of this paper is to decrease fuel consumption, increased efficiency of energy utilization and assuring that new pollutants are not generated by new waste heat recovery system. In steel manufacturing company ladles are used to transfer molten metal from induction furnace to Concast department but while transferring molten metal it losses much of heat to the environment via convection & radiation from ladle. A ladle with high heat content is desirable for steel making .Casting into cooler ladles also leads to high localized wear due to thermal spalling. A possibility of specific casting advantages, lowering in tapping temperatures and associated cost savings occurred by minimizing heat loss from the melt led to the concept of preheating and insulation in the steel ladles. The use of insulating linings allows companies to adopt a lower tapping or holding temperature practice and to reduce the variation in metal pouring temperatures. This results in improved control of metal chemistry, lower energy consumption, a reduction in furnace refractory consumption, and fewer slag inclusions and temperature-related casting defects. By preventing heat losses from ladles we can reduce considerable heat & power consumption.**

***Index Terms* —Insulating material, Heat loss, Ladle shell temperature, Furnace tapping temperature, Energy consumption**

I. INTRODUCTION

Currently steel industries are the largest energy consuming sector in the world, accounting for 15% of world's industrial energy consumption. Steel industries all across the globe are highly energy intensive, of the total cost of producing steel 20% is spent on energy. The increasing cost of energy and even its current and future availability shows the need to refocus attention on energy conservation in steel production. In most of the steel industries some heat cannot be useful for converting into any useful work & goes waste so it becomes essential to save this heat either by using recovery equipments or by using some heat resisting components.

The introduction of continuous casting & the enlargement of secondary metallurgy in steel plant caused that the ladle ceased to be just a media/ container for transport of molten metal from the primary unit (Furnace Section) to the caster. Ladles are generally refractory-lined, vertical cylindrical vessels that are closed at one end and usually open at the top and also a small off centre casting nozzle in the base. They consist of an external steel shell (20-100 mm thick), and several layers of internal refractory lining (up to 400 mm). When a heat is ready to be tapped from the furnace, the molten metal is poured into a ladle and transported, usually via an overhead crane, to the casting station. Common shape of ladle is vertical cone shape & ladle size is depending upon the capacity of the molten metal to be poured. In continuous casting, thermal control of liquid steel plays an important role in product quality and ladle refractory life. A small difference between targeted and achieved temperatures on teeming may have very negative consequences for surface quality, cleanliness, tundish flow through, nozzles, casting schedules, energy economy, *etc.*

The amount of energy that is lost from liquid iron during typical foundry operations in steel plant look at some preventive measures as well as the benefits of more effective heat conservation in liquid iron. During processing liquid iron in ladles & holders, there will be a continuous reduction of temperature due to heat losses from conduction through refractory lining & radiation from hot surfaces of ladle, in order to keep usable pouring temperature into the mould, these heat losses must be compensated by excess tapping temperature in the furnace. This in turn leads to increase cost of heating the iron as well as higher alloy consumption & refractory wear. By means of effective heat conservation, the losses & the consequences can be minimized & thereby reduce the overall cost of produced iron.

Tapping of the steel melt from the furnace into the ladle is accomplished by a very rapid drop in the melt superheat. The time for which the melt can be maintained in its superheated state depends on the tapping temperature, the extent of ladle preheat, the time taken to fill the ladle, ladle refractory material properties & the thickness of slag cover. Tapping temperature loss can thus be attributed to the following reasons; heat loss by pouring stream to the atmosphere by radiation, heat loss by convection to the slag layer & heat loss to the ladle walls as the ladle is filled. Once the ladle is full, the melt is held in the ladle for some time before casting, in this intervening period, the melt continuous to lose heat to the ladle walls & to the atmosphere .The process assuming a linear drop in the hot face temperature from 1650°C to 1560°C in one & half hour. The use of insulating linings allows foundries to adopt a lower tapping or holding temperature practice and to reduce the variation in metal pouring temperatures. This results in improved control of metal chemistry, lower energy consumption, a reduction in furnace refractory consumption, and fewer slag inclusions and temperature-related casting defects.

II. NEED OF INSULATION

i) To maintain ladle lining temperature:-

The temperature of ladle lining will directly affect the quality of liquid steel and ladle's service life. The reason is that when molten steel with temperature 1650°C is poured into the ladle, the working layer of ladle lining is heat insulation material & if working layer did not reach the required temperature of 1000°C during ladle baking, the molten steel liquid is directly injected into ladle that will cause great thermal shock to the working layer and bottom of ladle, this will causes the damage of working layer and refractory material of ladle, thus reducing the service life of the ladle. Meanwhile, molten steel will lose a lot of heat in the ladle, and then molten steel temperature will drop dramatically. Molten steel temperature of continuous casting must be controlled strictly to ensure the molten steel temperature within a narrow temperature range that can make sure the smooth progress of continuous casting.

ii) To reduce tapping temperature & power consumption :-

Survival of industries in such a period where rates of raw materials & electricity increasing continuously, it becomes essential for each company to reduce non value added activities to compensate this hike. Now a day's energy saving is much more essential for industry where rates of electricity is increasing drastically. By reducing tapping temperature of molten metal in induction furnace electricity can save.

iii) To maintain molten metal temperature in ladle:-

Ladle is only a molten metal storing device so there is less chances of any accident & interrupting of production cycle if any modifications done in ladle technology. Heat loss from ladle badly affect the quality of billet & TMT bar production in case of hot rolling as molten metal remains in ladle nearly for 60 min & during that period temperature of molten metal drops continuously as time progress, so temperature goes below required temperature & molten metal gets solidified so fluidity of metal gets affected & billets having less temperature may leads to break out & rolling mill roughing role crack so maintaining temperature in ladle becomes important for smooth casting & further work. If temperature in ladle remains constant or heat loss minimizes then tapping temperature for furnace may also reduced to some extent which also leads to saving electricity which plays a major role in company profit. Such types of savings & benefits focused on incorporating insulation to the ladle.

iv) To reduce heat loss & work of oil preheater:-

Ladle heat content plays a significant role in this drop in temperature & hence efforts are always directed towards minimizing the heat loss & maximizing the heat content. Moreover , tapping into colder ladle leads to high localized refractory wear due to spalling & thermal shocks & associated operational problems so for this reason ladle preheating & insulation have been receiving increasing attention.. Efforts to minimize heat loss of liquid steel through the ladle lining led to the idea of integration of high-quality insulating layer between the permanent lining and the ladle steel shell .Ladle linings with insulation may offer superb thermal insulation compared to conventional refractory systems. The use of insulating linings allows foundries to adopt a lower tapping or holding temperature practice and to reduce the variation in metal pouring temperatures as ladle lining remains hot for long time. This results in improved control of metal chemistry, lower energy consumption, a reduction in furnace refractory consumption, and fewer slag inclusions and temperature-related casting defects. If the temperature is too high, the adverse effect of centerline segregation increases or in extreme cases even a breakout can occur. If the temperature is too low, nozzle clogging and subsequent steel contamination with macro inclusions is possible. Under certain circumstances, low temperatures can even result in steel freezing in the nozzle.

v) To reduce skull formation:-

Casting temperature of the melt is of paramount importance to the solidification behavior of the castings. A considerable loss in heat content of the melt occurs from the time it is tapped to the end of casting & is evident from the accompanying fall in temperature. When molten metal enters in the ladle the temperature is more than 1600°C. Ladle directly contact with ambient temperature so due to this temperature variation heat transfer takes place & temperature of molten metal is reduced due to heat transfer. When temperature drop occurs in the ladle, solidified material produced inside boundaries of ladle called "skull". Skull formation is low if heat transfer in ladle is less. Skull formation in the ladle can be reduced by using insulation material to minimize the heat transfer through walls & more heat content will be in molten metal so skull formation will also be reduced. Molten metal temperature is very high so high temperature insulation material can be used.

vi) To reduce ladle shell temperature without compromising volume of ladle:-

In order to safely obtain the benefits of thinner linings and longer campaigns in steel ladles, it is necessary to insulate the lining. The steel shell loses strength, expands, contracts, and permanently deforms from over exposure to heat. One thing to reduce consumption is by reducing tapping temperature of molten metal. This objective can be achieved by reducing the heat losses in ladle. Efforts to minimize heat loss of liquid steel through the ladle lining, led to the idea of integration of high quality insulating layer between the permanent lining & ladle shell.

III. METHODOLOGY

i) Components in Ladle System

Ladle

Fig. 1 – Ladle

Fig. 2 – Silica Brick

The ladle ceased to be just a media/ container for transport of steel from the primary unit (Furnace Section) to the caster. Ladles are commonly used to transport molten metal from melting furnaces to casting stations in metal production facilities. Ladles are generally cylindrical, with an open top, and a small off centre casting nozzle in the base. They consist of an external steel shell (20-100 mm thick), and several layers of internal refractory lining (up to 400 mm).

Silica Bricks:-

Ladle is a bucket shaped steel vessel having thickness of steel sheet about 20 mm. For preparing safety lining silica sand bricks are used in inner shell. There are three sizes of bricks which are used for preparing safety lining. Figure 2 shows silica bricks.

1) 230*115*75 mm
2) 230*115*50 mm &
3) 230*115*40 mm

After safety bricks safety linings are prepared which is of silica ramming mass which holds molten metal.

Ladle Former:-

Ladle former is a conical shaped vessel made up of mild steel plate having thickness 3 mm. This former is placed in ladle to support patching. It is placed in ladle vertically when bricks are applied to the ladle inner shell. Former creates wall of ramming mass when ramming mass inserted in the space between ladle inner shell made up of bricks & former.

Ramming Mass:-

Ramming mass is a silica Quartz powder having different sizes from fine powder to 5 mm. Ramming mass contains approx. 1 % boric acid & it works as a binder.

ii) Preparation of Ladle lining

In Traditional patching process silica bricks fitted directly on ladle inner shell by using "WhyHeat A" cement & this lining is called safety lining. Each bricks placed one over other vertically starts from bottom till the top of ladle. Make sure that Bricks lining done all around circumpherentially at inner side. Next step is to patch with ramming mass over that silica bricks. For patching with silica ramming mass firstly place ladle former inside the ladle & match its center with ladle bottom center, once the center is match then fill the gap between safety lining & ladle former with ramming mass & rammed this powder with ramming tool till it compact properly & no air gaps remain in it. Layer of ramming mass is called working layer & it holds molten metal throughout entire process

Fig. 3 – Ladle after patching

iii) Ladle working Cycle

When we have to take ladle for tapping firstly it has to be preheated by means of oil preheater to gain required initial temperature to avoid thermal shocks. When ladle is red hot then only it becomes useful for tapping. Next to preheating tapping of molten metal from furnace is done in ladle when molten metal temperature in furnace reaches near about 1650°C. Once tapping done in ladle it sends to the Concast department where ladle is hold for some time to complete purging & alloy addition if required. When molten metal gain required temperature for casting then it placed on turret for casting process. Casting process requires about one hour, after completion of casting ladle sends to remove slag & cleaning ladle nozzle & for further maintenance work if required. After completion of maintenance work again same process of preheating & tapping is done on traditional ladle.

In every ladle cycle ladle needs to be preheated as there is much loss of heat through ladle lining so there is wastage of furnace oil as there is use of oil preheater to preheat ladles & every time tapping temperature has to increase as no retention of heat in ladle. So it becomes essential to prevent loss of heat from ladle shell.

IV. HIGH STRENGTH CERAMIC FIBER BOARD (INSULATING TILES)

High strength ceramic fiber Boards are having high compressive and flexural strength and good resistance to erosion from gas flow than normal Ceramic fiber boards. High strength Boards are designed to meet the toughest knocks and pressure maintaining its strength over a long productive life. It has low shrinkage compared to other fiber products. Ceramic fiber is a low thermal mass insulation material, which has revolutionaries the furnace design lining systems. Ceramic fiber is an alumino silicate material manufactured by blending and melting alumina and silica at temperature of 1800 – 2000°C and breaking the molten stream by blowing compressed air or dropping the melt on spinning disc to form loose or bulk ceramic fiber.

Fig.4 – Ceramic Fiber Boards

Table No. 01:-Properties of Ceramic Boards

Physical Properties	**HS-45**
Classification Temperature	**1260** °C
Chemical Compositions (%) (IS : 12107/ XRF	
Al2O3	**49-53**
SiO2	**33-37**
CaO	**9-12**
Loss on ignition (%)	**< 10**
Density (Nominal) Kg/ M3	**720**
Modulus of Rupture KPa < 25 mm Thick	**3000**
Modulus of Rupture KPa > 25 mm Thick	**2000**
Linear Shrinkage (%) – 24 Hrs (Max)	**1.0 (1200** °C**)**
Thermal Conductivity W/MK	
600 °C **(Mean Temperature)**	**0.16**
Thickness (mm)	
5	√
10	√
12	√
15	√

i. **Details about Tiles (Boards)**

Table No. 2- Details about tiles

Sr. No	**Item**	**Unit**	**Qty**	**Remarks**
1	Total surface area of ladle	Sq Cm	186,392	
2	Surface area of each tile	Sq Cm	500	(500*100*10 mm)
3	No of Tiles required for Lining	Nos.	746	(Two layers of 10 mm thick tiles)
4	Tiles required including wastage	Nos.	800	
5	Cost of each Tile	Rs	162	
6	Cost of 800 tiles	Rs	1,29,600	
7	VAT + Freight	Rs	12,000	Approx.
8	Total cost of Tiles	Rs	1,41,600	
9	Cost of relining	Rs	1,50,000	Cost includes breaking of two layers of safety lining. New safety lining shall be made over the insulation tiles.
10	Total cost for one Ladle	Rs	2,91,600	

V. PERFORMANCE ANALYSIS

Current study shows that ladle outer shell temperature reaches above 400°C when ladle life reaches above 100, which shows heat is losing to the environment to much extent & if we could maintain this outer shell temperature as less as possible then this will be the good achievement as current tapping temperature is above 1630°C. If shell temperature reduces means heat loss to the environment reduces then this will maintain required molten metal temperature in ladle while casting & till end of casting so tapping temperature can reduced to 1600°C - 1610°C. Reduction in heat loss will retain ladle lining temperature so work of preheating also reduces.

i. Study of outer shell temperature of ladle

Study done on traditional ladles is mentioned in following table & graphs. Some readings are taken on traditional (non insulated) ladle with varying ladle life. Graph indicates ladle as well as ladle outer shell temperature & it is seen that as ladle life increases ladle outer shell temperature also increases. From table & readings it is cleared that outer shell temperature reaches about 411°C which is loss to company as it will increase heat loss.

Table No. 3- Readings taken on traditional ladles

Sr. No	Ladle Life	Furnace Tapping Temp. °C	Ladle molten metal temp. on CCM °C	CCM Lifting Temp.	Tundish Molten Metal Temp.	Ladle outer shell temp. in °C
1	138	1624	1608	1589	1532	291
2	139	1621	1605	1584	1531	302
3	140	1627	1612	1591	1532	313
4	141	1624	1608	1587	1530	325
5	142	1636	1615	1603	1535	318
6	143	1631	1615	1598	1530	326
7	144	1628	1616	1589	1530	337
8	145	1624	1612	1586	1529	346
9	146	1629	1615	1589	1530	356
10	147	1634	1618	1592	1530	363
11	148	1642	1622	1606	1535	352
12	149	1631	1615	1598	1533	364
13	150	1626	1608	1586	1528	372
14	151	1620	1604	1589	1529	381
15	152	1627	1612	1594	1531	388
16	153	1618	1599	1591	1530	394
17	154	1624	1608	1593	1530	402
18	155	1621	1601	1598	1531	411

X-Axis:- Ladle Patching Life, Y –Axis :- Outer Surface Temp. of Ladle in °C

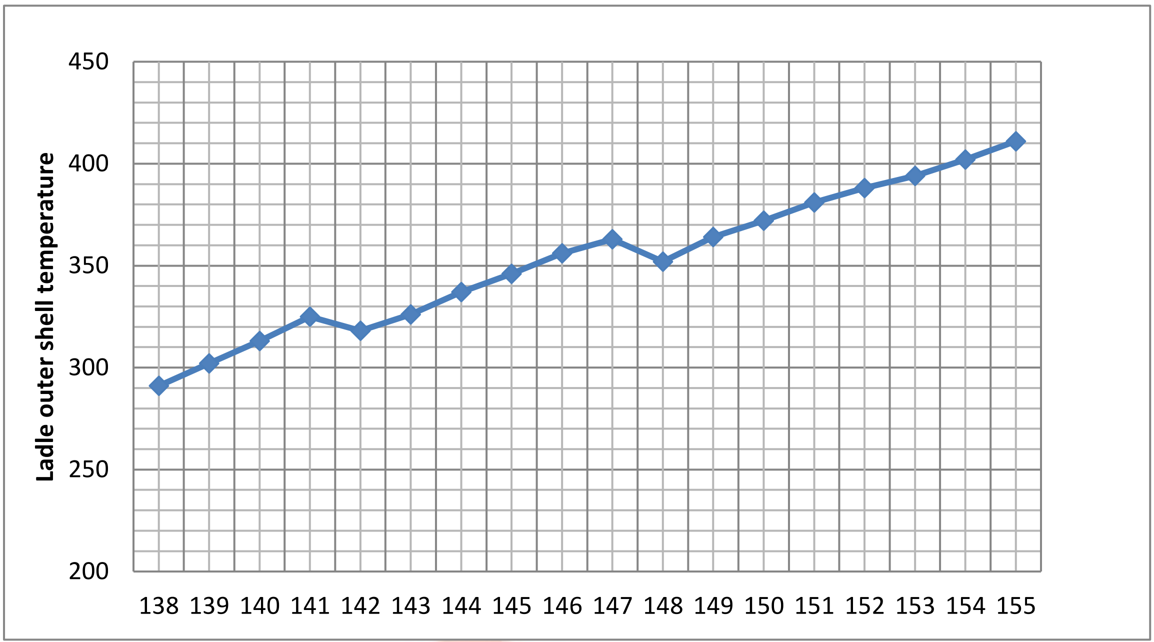

Fig. 5 - Figure showing ladle outer temperature

ii. Cost Saving Calculation

Case 1:- If heat transfer from ladle per hour is reduced by 20 °C, then we will have to take 20 °C less temperature in furnace while tapping. Tapping can be done on 1630d°C instead of 1650°C.

While taking temperature at 10,000 KW power & with 28 MT metal total rise in temperature is 15 °C in 1 minute.

By reducing tapping temperature of molten metal by 20°C then we can save 48 sec for total power 16,500 KW in one heat.

From above assumption in every heat if we save 0.8 min then we can save total 14.4 min in a day. (Considering one heat of 3.00 Hrs & No. of heats per day = 18 Approx.)

In one minute, Total units saved = 270

So, In 14.4 minutes, We can save units = 3888

Total saving in cost = Rs 23,328/- per day. (Approx)

Also if we consider other cases we will get various results as shown in table,

Table No.4 - Table showing costing at various temperature reductions

Sr. No	Reduction in Ladle Surface temp. in °C	Original Tapping Temp in °C	New tapping Temp. in °C	Total unit saved per heat	No of Heats per Day	Units Saved per Day	Rate of Electricity (Rs/Unit)	Total Saving per Day in Rs
Case 1	**25◦C**	1640	1615	278.33	18	5010	6	**30060/-**
Case 2	**20◦C**	1640	1620	222.22	18	4000	6	**24000/-**
Case 3	**15◦C**	1640	1625	166.67	18	3000	6	**18000/-**
Case 4	**10◦C**	1640	1630	111.11	18	2000	6	**12000/-**
Case 5	**05◦C**	1640	1635	55.56	18	1000	6	**6000/-**

iii. Tentative Action

Furnace tapping temperature as well as ladle outer shell temperature is most important factors. For taking furnace molten metal temperature we use R type thermocouple instrument which gives accurate reading up to 1800 °C & for taking ladle outer shell temperature we can use infrared thermometer which shows temperature up to 500°C.

Our main consideration is to save temperature drop in ladle via conduction & convection through ladle shell, saving in drop page we can take less lifting temperature on CCM which may directly affect Furnace tapping temperature. For example, consider we could save 10°C temperature drop in ladle then for casting operation we can lift ladle with 10°C less temperature (Suppose 1580°C instead of 1590 °C). For taking lifting temperature1590°C we have to tap heat with 1650°C & in same case we can tap heat with 1640°C for 1580 °C, so from this assumption we can say that we can save electricity which can be used for increasing this 10°C temperature. By calculating actual temperature drop & saving electricity we can calculate actual saving in rupees & other related benefits.

Comparative study of insulated & non insulated ladle will show better result & for that we require ladle shell temperature before & after tapping which will show how much temperature is raised against tapping temperature of furnace. For same patching life of insulated & non insulated ladle the shell temperature will show temperature loss from walls.

Ladle holds molten metal above 60 min while casting & much of the heat loss occurs at that time so while casting we can take ladle shell temperature after some specific time. After finding temperature in degree Centigrade it will be possible to calculate required unit to raise that temperature in furnace so from that we can calculate approximate saving in Rupees by incorporating insulation to the ladle.

Ladle life is one of the most important parameter as ladle life increases heat losses through ladle shell also increases because thickness of safety lining goes on decreasing , so it is important to monitor ladle shell temperature for each changing ladle life. Furnace temperature of each lot is important for calculating heat loss analysis as we have to minimize furnace temperatures which will leads to save power consumption. Consider molten metal temperature before tapping. Ladle molten metal temperature at CCM indicates how much temperature we have to drop for further process due to which we can do smooth operation .

Modern ladle technique will use insulation to the ladle of ceramic fiber board. These ceramic boards applied to the inner side of the ladle shell & over which silica bricks as a safety lining. The working layer is formed of ramming mass over safety lining. Ceramic boards have less thermal conductivity & good strength so we select these boards for our project.

From thermal equations of heat loss formulas or from actual data of total energy consumed from Energy meter (PDLM) to increase molten metal temperature in furnace (tapping temperature), we can calculate heat loss from ladle as well as total energy consumed to gain required temperature & total power saved.

VI. ADVANTAGES

1) Ceramic boards have very high strength
2) It reduces Thermal shocks
3) Use of Ceramic boards reduces chances of formation of skull
4) Increased productivity due to reduced superheat requirements & there by less time in the furnace.
5) Reduces Power consumption as well as alloy consumption
6) Maintain molten metal temperature in ladle
7) Furnace patching life increases as tapping temperature decreases.
8) Increase safety of ladle operation by reducing outer shell temperature

VII. CONCLUSION

1) After incorporating insulating boards we can reduce furnace tapping temperature.
2) We can reduce CCM lifting temperature.
3) With the help of these boards we can reduce the ladle shell temperature. This results in better heat storage in ladles and tundishes. On account of better heat retention in ladle and tundishes in the number of cases of liquid metal returning from casters due to low temperature may significantly come down.
4) By the application of insulation boards we can achieve our main objective of reduction of power consumption..
5) Average payback period can be approx 22 days.
6) Reduced heat transfer through walls leads more heat content in molten metal so skull formation may also reduce in ladle.
7) Minimize degradation of ladle shell due to hot spots and high shell temperatures.
8) Less thermal shocks during tapping if refractory have required initial temperature.
9) Huge savings are possible with this modification

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