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TO STUDY ENERGY CONSERVATION IN FOUNDRY BY USING PROCESS PARAMETERS

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ABSTRACT

The foundry industry is energy intensive and has an important role to play from an environmental point of view whereas seeking to develop and play an important role in the nation's continued economic development. The energy conservation has been done by various methods and it can be conserve by using various process parameters such energy consumption audit which gives detailed information about utilization of energy in various sections and identifies areas of improvement. Specific energy consumption is reduced with increased capacity utilization by energy accounting method. Various heat losses through furnace wall are calculated using the method of steady state heat conduction through a multilayer lining wall. Consumption of energy depends upon quality of raw material, size, shape, cleanliness and density. In this paper induction furnace model is prepared in ANSYS software then data is simulated with existing data and result are calculated.

INTRODUCTION

Energy is the primary and the most universal measures of all kinds of work by human being and nature. Electrical energy is proved to be an ideal energy in all sorts of energy available in nature. The increasing demand for power has led to considerable fossil fuels burning which has in turn had an adverse impact on environment.

Energy conservation means energy prevention from being wasted more than its purpose of use such as turning off lights on a frequent basis and not extremely cooling rooms with air-conditioners, and improvement of efficiency of energy use through technological improvement. Electric energy means the "electricity" that is produced in a power plant, transmitted by transmission lines, and can be obtained by paying for utilities. Generally, electricity can be obtained through an outlet or battery and can be used as motive power for electrical products such as televisions and refrigerators. Heat energy and electric energy are used in a variety of ways, depending upon equipment or facilities in use. Normally, they cannot be used at 100% of full efficiency, and some losses occur. For instance, at offices, if personal computers are operated only while users look at their screens, the best efficiency will take place. However, in fact, while users are on the telephone, or serving customers, screens are still displayed. Electric energy is wasted during such time. Although more computers have function of energy conservation automatically becoming standby mode when untouched after a certain period of time, it is impossible to turn power on only while users look at screens. The same type of energy losses occurs to many aspects of energy consumption in larger size such as power plants in factories throughout society. Energy conservation is expected to reduce these kinds of losses of energy in the entire society as much as possible and aim to raise the efficiency of energy use as close to 100% of the full rate. In foundries energy accounting is necessary to determine where and how energy is being consumed and how efficient is the energy management system. There are many opportunities for improving energy efficiency in most foundries. Some of these, such as optimizing the efficiency of ancillary services can be achieved at minimal cost and make a valuable improvement to the bottom line. Reports from many foundries suggest that energy efficiency is one of the most significant cleaner production options still to be addressed in the industries. The study reveals that the two thirds of the energy consumed in a foundry are used for metal casting and holding operation. Considerable energy saving can be achieved by proper attention to this process with proper energy management. This report gives an idea of the current energy consumption of the foundries, which can be compared with standard norms and can be used to implement in Indian foundries [4]. Figure 1 shows the power distribution tree of foundry.

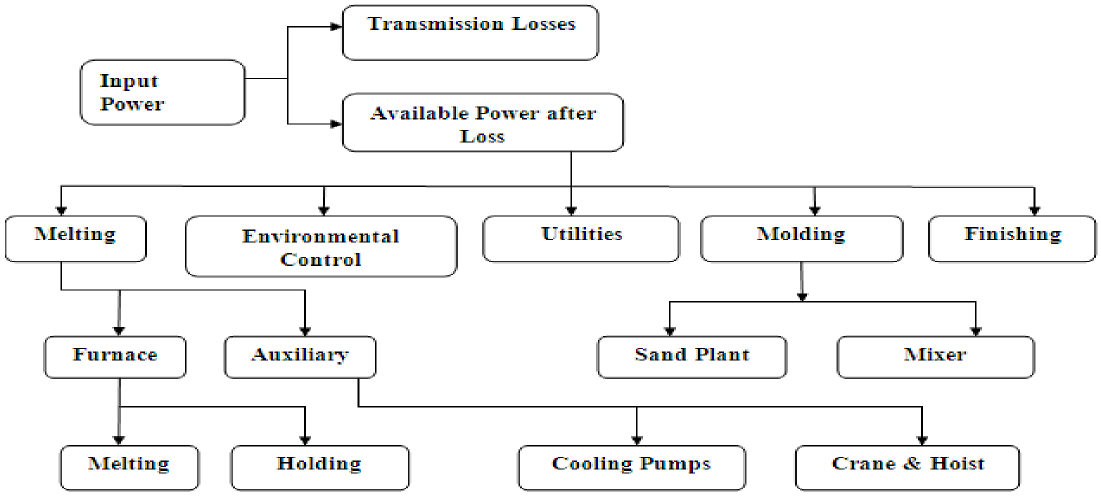

Fig.1 Power Distribution Tree of Foundry [5]

Various parameters are used to conserve the energy in foundry. These parameters are energy audit, proper furnace lining material, quality of scrap, Ramming material, Holding of material, power input, scrap charging, transfer of metal.

ENERGY AUDIT

Energy audit gives detailed information about utilization of energy in various sections and identifies areas of improvement. Specific energy consumption is the energy consumed per ton of liquid metal produced. The collection of data has made use of metering facilities for energy consumption in different sections/ equipment's. Optimizing capacity utilization is largely dependent on factors such as production planning capabilities and increasing the number of equipment options available for production. Methodology of energy consumption studies and process flow explained in figure 2

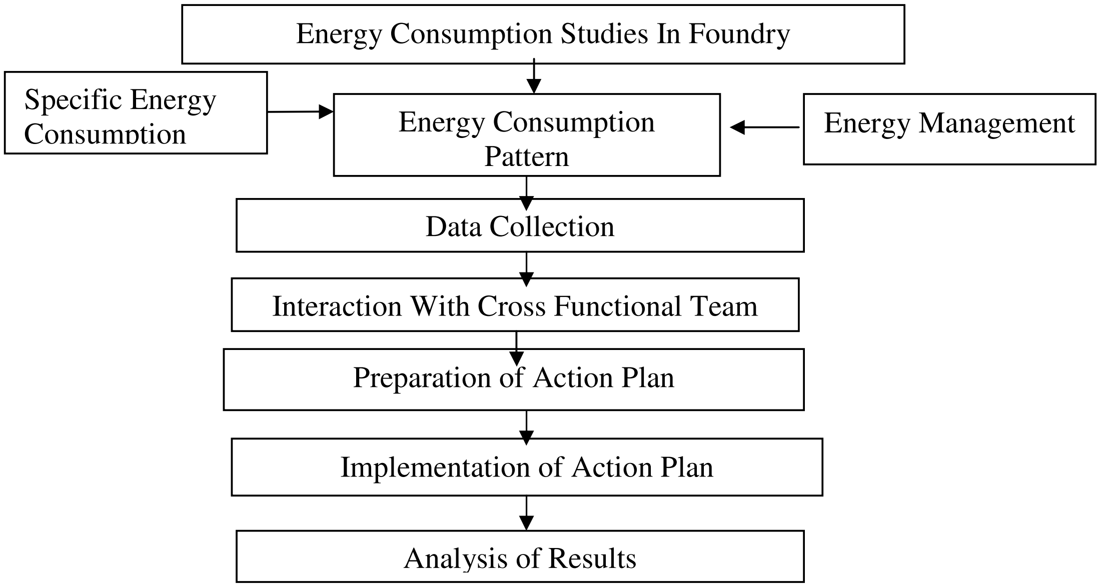

Fig. 2 Methodology for Energy Consumption Studies

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Table-1 Energy Consumption in C.I. Foundry

Sr. No.	Consumption	Units(kWh)	Percentage
1	Furnace	364808	74.45
2	Line-1	77778	15.87
3	Line-2	10425	2.1276
4	Cooling Pump	31262	6.38
5	Other	5701	1.16

Above table shows the energy consumption in C I foundry among these largest amount of energy to the tune of 65 – 75 % of the total foundry energy is consumed in melting operation. Cycle time required for melting operation is also important parameter. It is depends upon power input, raw material and activities related cycle time such as charging, de-slagging, composition adjustment. For induction furnace energy efficiency depends on the effectiveness of lining material and cooling system. Holding of material reduces furnace lining life consumes more power this happens because of breakdown in the production line and improper scheduling of furnace. For this it is essential to calculate various losses in various furnace sections

HEAT LOSS CALCULATION

In order to find the heat model of the furnace, we use the heat balance equation of the furnace for consideration. The pattern of heat balance equation is as follows.
Heat input = Heat output + Heat loss
Upon considering the heat losses (heat), they consist of the heat losses from transferring the heat from furnace wall to the coil, the heat losses from radiation at the furnace, heat losses from the heat induction of the cooling water system, and other heat losses. The mechanism for the heat losses depends on the temperature and upon considering the heat losses (electricity). The characteristics of the losses depend on the volume of electricity and resistance [24]. Table 2 shows that materials used for furnace charging.
Heat input = 1700 kW

Table-2 Materials for Furnace Charging

Sr. No.	Material	Weight (Kg)
1	Runner Riser of cast iron	1270
2	M.S. Scrap	525
3	Pig Iron	1100
4	Ferrosilicon	20
5	Ferromanganese	5
6	Petroleum Coke	18

Where,

M= Mass (Kg)
Mw= Flow rate of cooling water (kg/sec)
Cp= Specific heat capacity (kJ/Kg K)
T_1= Temperature of liquid cast iron (K)
T_2= Temperature of solid cast iron (K)
Δt = Melting time (sec)
R= Heat resistant of furnace lining (kW/K)
ε= Emissivity of ramming mass
σ= Stefan Boltzmann constant = 5.669 x e-8 W m^{-2} K^{-4}
L= Latent heat (kJ/kg)
Cpw= Specific heat capacity of water (kJ/KgK)

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HEAT GIVEN TO CAST IRON

$Q_{CI} = \frac{M \times L}{\Delta t} + \frac{M \times Cp \times \Delta T}{\Delta t}$ ………………………………………… (1)

$Q_{CI} = \frac{1270 \times 209}{3600} + \frac{1270 \times 0.5 \times 1480}{3600}$

Q_{CI} = 334.78 kW

Heat given to M.S. Scrap

$Q_{MS} = \frac{M \times L}{\Delta t} + \frac{M \times Cps \times \Delta T}{\Delta t}$

$Q_{MS} = \frac{525 \times 272}{3600} + \frac{525 \times 0.682 \times 1480}{3600}$

Q_{MS}= 186.85 kW.

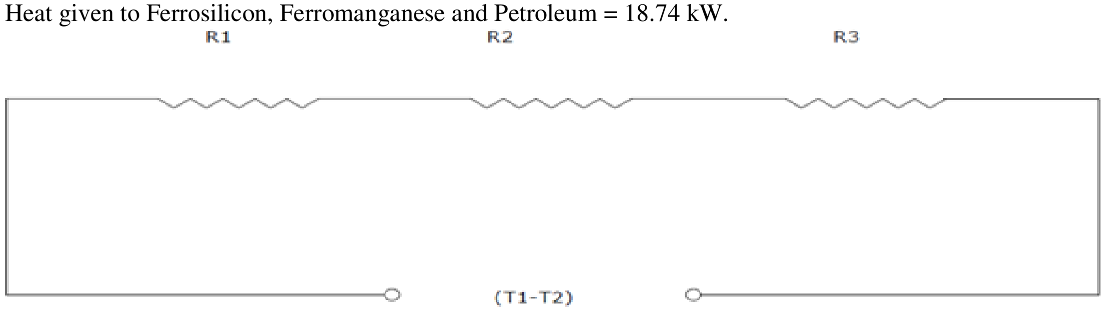
Heat given to Pig iron

$Q_{PI} = \frac{M \times L}{\Delta t} + \frac{M \times Cps \times \Delta T}{\Delta t}$

$Q_{PI} = \frac{1100 \times 209}{3600} + \frac{1100 \times 0.54 \times 1480}{3600}$

Q_{PI}= 308.06 kW.

Heat given to Ferrosilicon, Ferromanganese and Petroleum = 18.74 kW.



Resistance Analogy of Furnace

$Q_{\text{conduction}} = \frac{(T1-T2)}{\sum R}$ ……………………………………………..……… (2)

$Q_{\text{conduction}} = \frac{1460}{0.008938}$

$Q_{\text{conduction}}$=163.33 kW

Heat loss due to radiation

$Q_{\text{radiation}} = \varepsilon \times A \times \sigma \times (T_i^4 - T_o^4)$ ……………………………………………….. . (3)

$Q_{\text{radiation}} = 0.45 \times 3.14 \times 0.347^2 \times 5.667 \times 10^{-8} \times (1500^4 - 40^4)$

$Q_{\text{radiation}}$= 48.8617 kW

Heat loss to cooling water $= Mw \times Cpw \times \Delta t$ …………………………………..…… (4)

$= 7.5 \times 4.2 \times 13$

$= 409.5$ kW

Heat loss in generator panel and capacitor bank = 119 kW

Unaccounted heat loss = 110 kW.

Most of energy supplied is utilized for melting of metal i.e. for sensible and latent heat. Heat loss through furnace wall is calculated by considering resistance analogy. Heat loss from furnace include conduction loss, radiation loss, heat gained by cooling water, loss in generator and capacitor bank. Also there is significant loss of energy considered as unaccounted heat loss.

QUALITY OF RAW MATERIAL

- Quality of raw material is not good.
- Foundry return raw material having sand mass attached with it.

During the melting process, slag is generated from oxidation, dirt, sand and other impurities. Slag can also be generated from the scrap, erosion and wear of the refractory lining, oxidized ferroalloys and other sources. In a coreless induction furnace, slag normally deposit along the upper portion of the lining or crucible walls and

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above the heating coils. Almost every vessel that holds or produces liquid iron is lined with refractory materials and is susceptible to refractory erosion by slag. In other circumstances, slag can combine with refractory materials to form accretions that hamper production. The consequences of refractory problems, loss of production and the cost to replace the refractory can be serious. Thus, extending the life of a refractory lining is an important consideration. Figure 3 shows the raw material used for furnace charging.

Fig. 3 Raw Material Used for Furnace Charging.

Iron oxide is present in large amounts in many of the slag found in foundry vessels and furnaces. Unfortunately, iron oxide is among the best solvents for refractories, and in particular it is a very good solvent for silica refractories. Figure 4 shows how slag is formed on furnace wall.

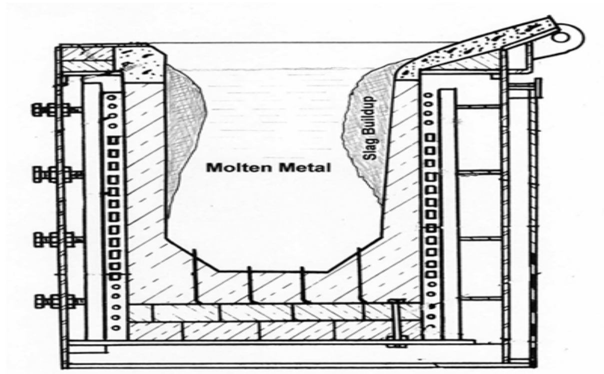

Fig. 4 Slag Built Up on Furnace Lining

TAPPING TEMPERATURE

Tapping temperature depends on type of material used for casting, number of components to be poured, pouring temperature range for particular metal, dimensions of the casting to be poured and distance between furnaces and pouring section. It was found that tapping temperature is more compared to pouring temperature. Figure 5 shows the graph of temp vs time

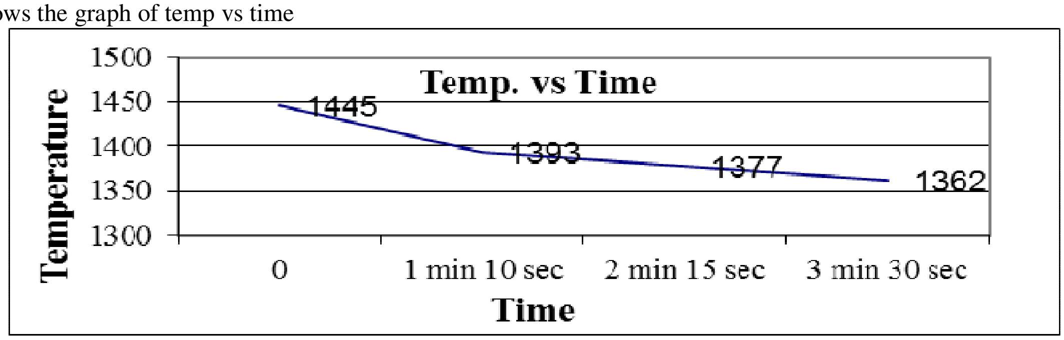

Fig. 5 Temperature Vs Time Graph

Table 3 shows the action plans for foundry.

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Table-3 Action Plan for C.I. Foundry

Sr.No.	Issue/Problem	Action Decided
1	Tapping temperature is more	Setting of proper tapping temperature
2	Quality of scrap	Tumbling barrel for foundry return scrap, raw material as per standard specifications
3	Life of lining	Electro herm machine for ramming
4	Melt rate per hour at cupola and induction furnace	Study of melting rate per hour at cupola and induction furnace.
5	Furnace lid randomly used	Continues use of furnace lid
6	Coke to metal ratio is less	Good quality of coke Increase preheating zone height of cupola no. 2

EXPERIMENTS

Design of Experiments (DoE) using Taguchi method is done to get orthogonal array. Considering the obtained array, the experiments are performed using L16 orthogonal array with clean raw material and bundled steel as process parameters and four levels units per ton as response variable. They are analyzed using ANOVA and interpreted [25].

PROCESS PARAMETERS

Table 4 shows the values of the selected process parameters, two parameters with four levels of each parameter. All these values are selected on the basis of literature review

Table 4 Process Parameters and their levels:

Sr. No.	Process Parameters	Level 1	Level 2	Level 3	Level 4
1	Clean Raw Material (Weight in %)	10	20	30	40
2	Bundled Steel (Weight in %)	5	10	15	20

Below figure 6 shows Furnace Charging Material Figure a indicated the raw material with sand and Figure b indicates the clean raw material.

(a) Raw Material with Sand (b) Clean Raw Material

Fig. 6 Furnace Charging Materials (a) Loose Steel **(b) Bundled Steel**

Table 5 shows that furnace loading chart used in foundry which contains information about use of materials for charging. Weight measurement of materials is carried out on weighing machine and it is noted in the chart before charging.

Table-5 Furnace Loading Chart

Sr. No.	Trial No.	Furnace No.	C.I. Scrap (Kg)	M.S. Scrap (Kg)	Pig Iron (Kg)	Ferrosilicon (Kg)	Ferromanganese (Kg)	Petroleum (Kg)	Total Weight (Kg)	Units (kWh)
1	1	F_2	C.R. = 273 R.R. = 817	B.S. = 137 L.S. = 409	P.I. = 1090	8	8	22	2742	1839
2	2	F_1	C.R. = 275 R.R. = 823	B.S. = 275 L.S. = 274	P.I. = 1098	7	8	18	2760	1838
3	7	F_2	C.R. = 274 R.R. = 820	B.S. = 410 L.S. = 137	P.I. = 1094	6	9	20	2750	1802
4	9	F_1	C.R. = 271 R.R. = 812	B.S. = 542 L.S. = 0	P.I. = 1084	5	7	21	2721	1771
5	3	F_1	C.R. = 545 R.R. = 545	B.S. = 136 L.S. = 401	P.I. = 1089	8	9	18	2733	1792
6	15	F_2	C.R. = 549 R.R. = 549	B.S. = 275 L.S. = 275	P.I. = 1098	7	8	22	2761	1778
7	10	F_1	C.R. = 543 R.R. = 542	B.S. = 407 L.S. = 136	P.I. = 1085	9	8	19	2730	1739
8	11	F_2	C.R. = 545 R.R. = 544	B.S. = 545 L.S. = 0	P.I. = 1090	8	8	20	2740	1721
9	12	F_1	C.R. = 820 R.R. = 274	B.S. = 137 L.S. = 410	P.I. = 1094	8	9	22	2752	1738
10	16	F_2	C.R. = 824 R.R. = 275	B.S. = 275 L.S. = 274	P.I. = 1098	7	8	21	2761	1720
11	14	F_1	C.R. = 817 R.R. = 273	B.S. = 409 L.S. = 136	P.I. = 1090	8	9	20	2762	1688
12	6	F_2	C.R. = 820 R.R. = 273	B.S. = 547 L.S. = 0	P.I. = 1093	9	9	17	2751	1678

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Table 6 shows results of experiments.

Table-6 Results of Experiments

Sr. No.	Clean Raw Material (Weight in %)	Bundled Steel (Weight in %)	Units per Ton (kWh)
1	10	5	671
2	10	10	666
3	10	15	659
4	10	20	651
5	20	5	654
6	20	10	644
7	20	15	637
8	20	20	628
9	30	5	632
10	30	10	623

ANALYSIS OF UNITS PER TON

Analysis of variance (ANOVA) for units per ton is given in Table 7. These values are obtained from Minitab 16 software. It shows that clean raw material and bundled steel both significant parameters for units per ton.

Table 7 ANOVA for Units per Ton (kWh)

Source	DF	Seq SS	Adj MS	F	P
Clean Raw Material (% wt)	3	8165.0	8165	1194.88	0.000
Bundled Steel (% wt)	3	1188.5	1188.5	173.93	0.000
Error	9	20.5	20.5		
Total	15	9374			
S 1.50923 R-Sq = 99.78% R-Sq(adj) = 99.64%					

The value of F ratio is greater than 4.75 for clean raw material and bundled steel hence both factors are significant. Figure 7 shows the relation between units per ton and respective process parameters. Here smaller signal to noise ratio is considered as better one, hence values of plot at top positions indicate better results.

Main Effects Plot for SN ratios for units per ton

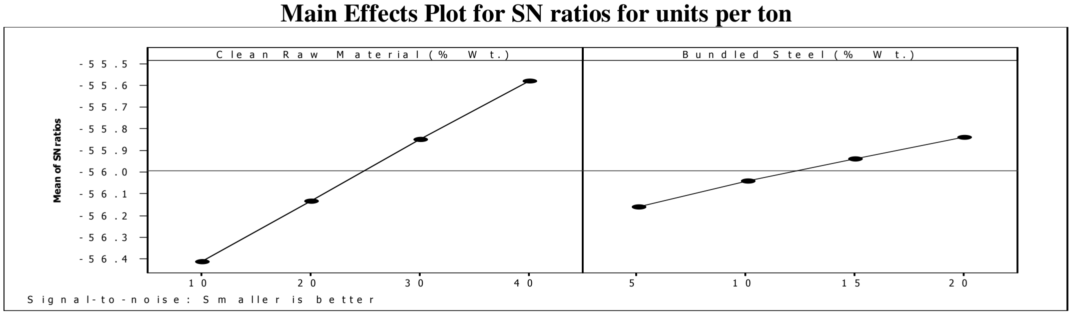

Fig 7 Main Effects Plot of SN Ratios for Units per Ton (kWh)

Units per ton decreases with increase in % of clean raw material and bundled steel Similar trend is observed by Ravichandran et al. [13] they tried with two combinations bundled steel and loose steel charge mix; cleaned and uncleaned scrap charge mix. The reason behind this is if foundry return raw material having sand attached with it if this material used furnace charging it requires more heat compared to clean raw material because sand having double heat capacity compared to cast iron. The scrap charge should be as dense as possible. Loose steel forms air pocket between scrap pieces, less is the power density. Use of bundled steel instead of loose steel forms lesser the air pocket between scrap pieces, more is the power density. Melting time significantly reduced by use of bundled steel. If raw material contains dirt, sand and other impurities then slag is generated during melting process. Slag can also be generated from the scrap, erosion and wear of the refractory lining, oxidized ferroalloys and other sources. Figure 8 shows the actions taken to reduce radiation loss from furnace by use of furnace lid.

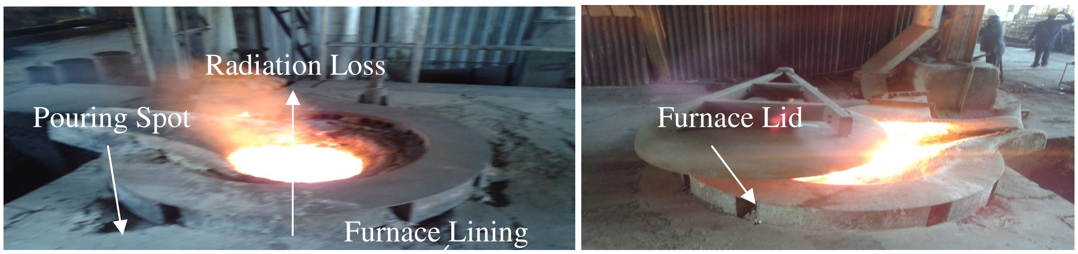

Fig. 8 (a) Radiation Losses from Furnace (b) Use of Furnace Lid

Based on drawing and dimensions of existing furnace a new model is developed using ANSYS. Thermal analysis carried out with steady state condition because of its actual values measured at steady state.

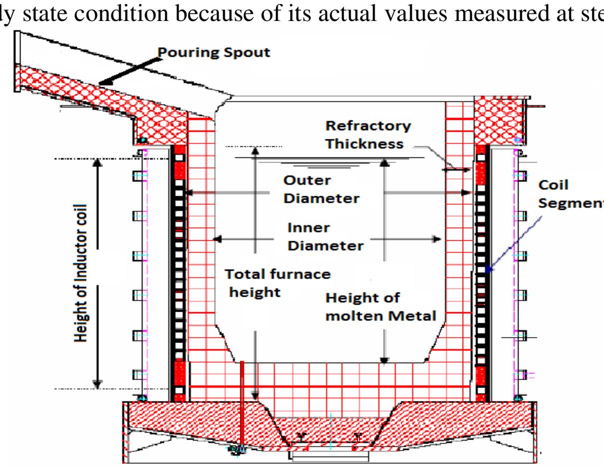

Fig 9 Furnace Drawing

Figure 10 A and 10 B shows the thermal analysis of furnace by using silica material and Zirconia Material

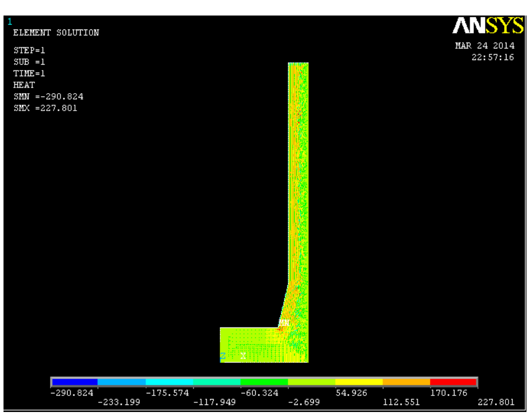

Figure 10 A. Silica Material

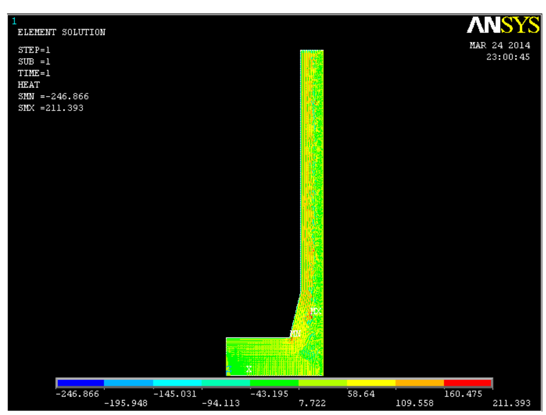

Figure10 B. Zirconia Material

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ANSYS analysis shows that furnace lining with silica material having heat loss of 227 kW. If we use furnace lining with zirconia material heat loss reduced to 211 kW. Similar trend observed by Mehta et al. [20] and Bara [21].Heat loss through furnace wall depends on properties of lining material like thermal conductivity, wall thickness, heat transfer coefficient and density. With use of low thermal conductivity material inside the furnace produces more resistance to heat flow which results in energy saving.

CONCLUSION

Present work shows that furnace is most energy consuming factor, almost 65-70 % of total energy consumed in melting division. Action plans are made by observing all processes carefully. Experiments are performed using clean raw material and bundled steel instead of unclean scrap and loose steel resulted in lower units per ton.

- Use of 40 % clean raw material and 20 % bundled steel gives saving of 34.81 units per ton in cast iron foundry.
- ANSYS analysis shows that zirconia lining material gives lower heat loss through furnace wall which is about 211 kW and heat loss from silica is about 227 kW.

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