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Energy saving and Performance Improvement of Induction Furnace by Thermal Analysis using ANSYS

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Abstract

In many casting manufacturing industry, Furnaces are most commonly used for melting of materials. Induction furnaces are more beneficial as no fuel is required. Especially silica ramming mass is used as refractory material to prevent losses. It is a problem to find life of Induction Melting Furnace wall under thermal fatigue. The induction melting furnace wall is made of silica ramming mass which is one kind of refractory material. In foundry industry, energy accounting is necessary to determine heat losses and how efficient is the energy management system. There are many opportunities for improving energy efficiency in most foundries. In this paper we have suggested alternative ramming mass material to silica ramming mass which is Zirconia (ZrO2).The thermal conductivity of Zirconia ramming mass is less so considerable energy saving can be achieved by proper attention to this process by thermal analysis of induction furnace by using ANSYS software. This paper deals with Thermal analysis of Induction furnace by using Silica and Zirconia ramming mass material for minimum heat losses during melting process. Heat loss calculation requires thermal properties and physical parameter. Calculations have been done for theoretical heat loss and temperature distribution which are later compared with actual values measured on existing furnace. ANSYS Software was used for thermal analysis which gave more accurate results.

Keywords*: - Thermal analysis, Induction furnace, Sili cramming mass, Refractory material, Energy management system, Heat losses.*

INTRODUCTION

Electrical energy is a high-grade energy in all sorts of energy available in nature. Energy is the prime mover of economic growth and is vital to the sustenance of a modern economy. Now a day's the increasing demand for electric power and the pursuit of its economical use. In addition, the requirements of minimum electric power losses and environment protection have become extremely important, that is the minimization of the heat losses.

Mostly there are heat losses by conduction, convection and radiation, and hence the improvement in best refractory material and optimization in wall thickness of refractory material is needed. The induction melting furnace wall is made of silica ramming mass which is one kind of refractory material. The Existing furnace is capable of melting nearly 0.5 tons per 40 minutes with power input of 500 kWh.

The main objective of this paper is to identify the problem related with the induction furnace and calculate heat losses through the side walls across the temperature distribution by using analytical methods. Verification of analytical result is compared with actual measured values on existing furnace and those are validated with ANSYS software. Model is prepared with existing dimensions in ANSYS software and is verified with the calculated results. For minimum heat losses thermal analysis of Induction furnace by using Silica and Zirconia ramming mass material is done with ANSYS software.

LITERATURE REVIEW

Prof. N. C. Mehta et al. [1] did thermal fatigue analysis of ramming mass with the help of ANSYS software. Firstly they have focused on construction of furnace and problem identification. They have prepared furnace model in the PRO-E software it is imported to ANSYS. Following are boundary conditions.

Environmental temperature is homogeneous at 25 °C, ignore the influence of heat convection, ignore the effect of gravity field, the surface of induction melting furnace wall is clean, the initial temperature of the induction melting furnace is set 25 °C and it is agreement with the ambient temperature during solving the problem, heat flux is considered constant for this analysis, scarp material input inside furnace is considered uniform for our analysis.

Nihar P Bara [2] carried out analysis for effective heat transfer of the induction process. The results show the effectiveness of ramming mass in the melting process. It plays an important role in the process. The simulation performed shows the proper thickness and conductivity of it would enhance the melting and optimizes the heat process. The result also highlights the application of FEM in the computation calculations of induction process.

Nitin Bhujbal and Kumhar S.B [3] reviewed optimization of wall thickness and material for minimum heat losses for induction furnace by FEA. They identify the problem related with the induction furnace and calculate heat losses through the side walls across the temperature distribution by using analytical methods. Verification of analytical result is compared with actual measured values on existing furnace and those are validated with APDL Ansys software. The purposes of this paper are studying the influence of process parameters on the energy consumption and finding the potential optimization of the refractory material of induction furnace.

M. M. Ahmed, M. Masoud et.al. [4] Reviewed the design of coreless induction Furnaces for melting iron. The electrical parameters of the furnace such as number of turns of coil, inductance of the coil, resistance of the coil and the maximum flux density were determined based on transformer concept, comparison of the obtained design results with the corresponding existing design results was done.

STUDY OF EXISTING FURNACE

Analysis of Existing Furnace

Based on drawing and dimensions a model of existing furnace is developed using Ansys. Following figure 3.1 shows Axis-symmetry about Y-Axis so for better result and accuracy we can solve it with Axis-symmetric condition.

Thermal analysis carried out with steady state condition because of its actual values measured at steady state.The temperature of wall drops steadily towards its outer surface, at which place the temperature exceeds that of surrounding air. Mostly furnace undergoes continuous heating process.

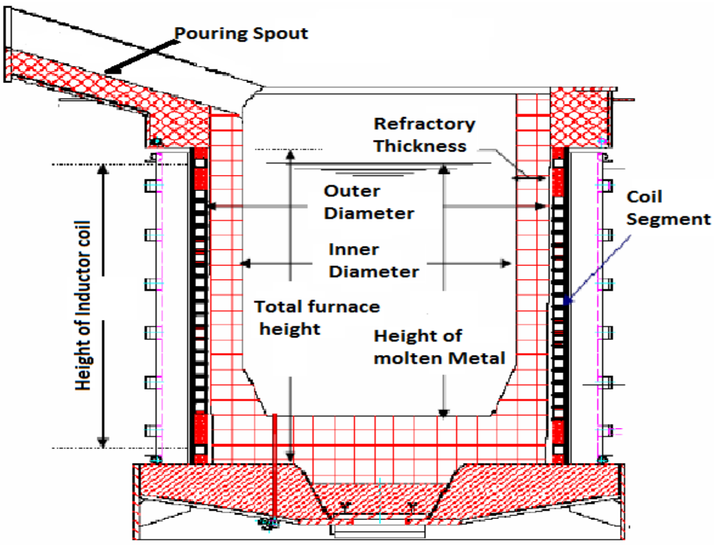

Figure 3.1 Model of existing furnace

Table No.3.1 Dimensions of furnace

Parameter	Notation	Dimensions in meter
Inner radius of furnace	R1	0.250
Outer radius of ramming mass	R2	0.350
Outer radius of Micasil	R3	0.354
Outer radius of steel	R4	0.364

Energy Consumption for Induction Furnace

Power supply-500 KW

Material- Cast Iron (Ductile, Nodular, Spheroidal CI)

Capacity- 500 Kg per 40 minute.

Maximum capacity 5-6 ton per day
200-220 ton per month

Electricity consumption

To melt 500 kg CI 290-310 kWh electricity required.

For 1 ton 600 kWh Electricity required.

In 1 month 220-225 ton CI melts.

Total consumption for month is 132000-132500 kWh or Units for each induction furnace so total electricity consumption for furnace is 264000 Units (kWh) per month.

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

Table No.3.2 Materials for furnace charging

Sr.No.	Material	Weight(Kg)
1	Runner Riser of cast iron	215
2	M.S. Scrap	85
3	Pig Iron	190
4	Ferrosilicon	2.5
5	Ferromanganese	1.5
6	Petroleum Coke	4

Heat input = 500 kW

M= Mass (Kg)

L= Latent heat (kJ/kg)

Cp= Specific heat capacity (kJ/Kg K)

Mw= Flow rate of cooling water (kg/sec)

Cpw= Specific heat capacity of water (kJ/KgK)

T1= Temperature of liquid cast iron (K)

T2= Temperature of solid cast iron (K)

Δt=Melting time (sec)

R= Heat resistant of furnace lining (kW/K)

ε= Emissivity of red hot body

σ= Stefan Boltzmann constant = 5.669 x e-8 W m2 K

A = C/S area of the furnace

Heat given to Cast Iron

QCI=

(M×L)/Δt + (M ×Cp×ΔT)/Δt……… (3.1)

QCI=

(215 × 209)/2400 + (215 ×0.5 ×1480)/2400

QCI = 85.01 kW

Heat given to M.S. Scrap

QMS=

(M×L)/Δt+(M×Cps×ΔT)/Δt………... (3.2)

QMS=

(85×272)/2400+(85×0.682×1480)/2400

QMS= 45.38 kW.

Heat given to Pig iron

QPI=

(M×L)/Δt + (M×Cps×ΔT)/Δt………. (3.3)

QPI=

(190× 209)/2400+ (190 ×0.54 ×1480)/2400

QPI=79.81 kW.

Table 3.3 Temperature distribution in existing induction furnace

Notation	Content	Temperature °C
Ti	Inner wall temperature	1500
To	Ambient temperature	40
Tw	Outer wall temperature	40 to 75
Twi	Inlet water temperature	25 to 35
Two	Outlet temperature of water	40 to 75

Heat loss due to Conduction

Q conduction=

((T1-T2))/(∑R) ……………… (3.4)

∑R = R1+R2+R3

R1 = ln (r2/r1) / 2πLk

R1=ln (0.35/0.25) / 2π* 0.75* 11

R1=0.00649

R2=0.0200

R3=0.001094

∑R = R1+R2+R3

∑R=0.02758

Q conduction = 1460/0.02758

Q conduction=52864.39 W= 52.86 kW

Heat loss due to radiation

Q radiation = ε × A × σ × (Ti4-To4)..... (3.5)

Q radiation= 0.43× π/4× 0.502× 5.667× 10-8× (15004-404)

Q radiation= 24222.35 W= 24.22 kW

Heat loss to cooling water

=Mw×Cpw×Δt…………… (3.6)

=2×4.187×13

=108.86 kW

3.4.7 Unaccounted heat loss = 103.86 kW.

ANSYS ANALYSIS

Element Selection

SOLID7O has a 3-D thermal conduction capability. The element has eight nodes with a single degree of freedom, temperature, at each node. The element is applicable to a 3-D, steady-state or transient thermal analysis. The element also can compensate for mass transport heat flow from a constant velocity field. If the model containing the conducting solid element is also to be analyzed structurally, the element should be replaced by an equivalent structural element (such as SOLID185). An option exists that allows the element to model nonlinear steady-state fluid flow through a porous medium with this option; the thermal parameters are interpreted as analogous fluid flow parameters.

Modeling

Create circular areas of three material ramming mass, micasil paper and steel shield as per dimensions given in Table No. 3.1 and extrude to form three volumes

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so that each volume can be assigned with respective material properties. For meshing create a volume 4 that will give the proper discretization of volume and uniform meshing.

PREFERENCE

Thermal, h method

h- Method is used when a variation occurs in the element according to element size. In existing analysis when elements size will change element will be changed automatically. So this method is more reliable for analysis.

Element type

Add element for different three materials with the Thermal Mass solid 8node 70 and insert element

Material properties

Material properties are important for analysis purpose; thermal conductivity and Density is added for structural, linear, elastic, isotropic for each material and change temperature unit with 0C.

Meshing

Meshing is the discretization of element in to small element for better accuracy. Mesh generation is the process of dividing the analysis continuum into a number of discrete parts or finite elements. The fine meshing has better result, but the longer the analysis time. Therefore, a compromise between accuracy and solution speed is usually made.

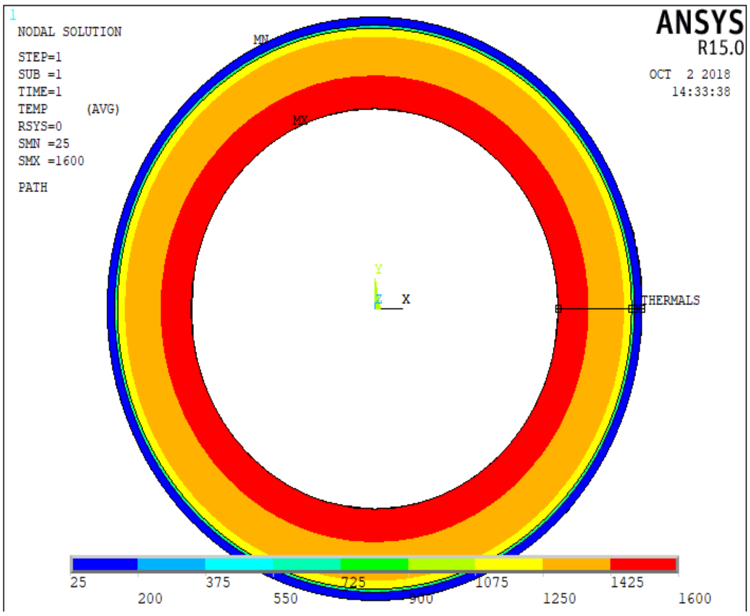

Figure 4.1 -Silica Nodal Temperature Distribution

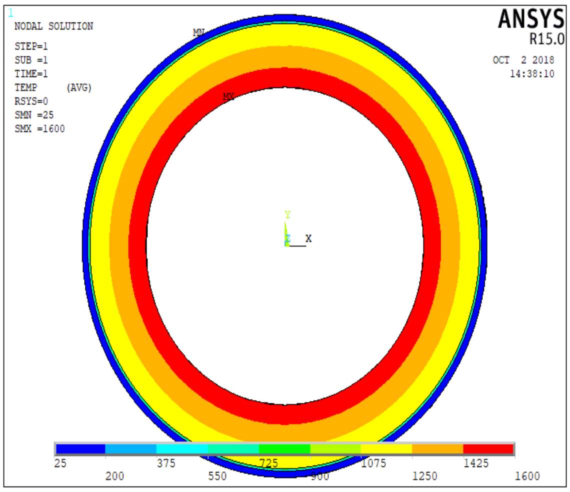

Fig 4.2 Zirconia Nodal Temperature Distribution

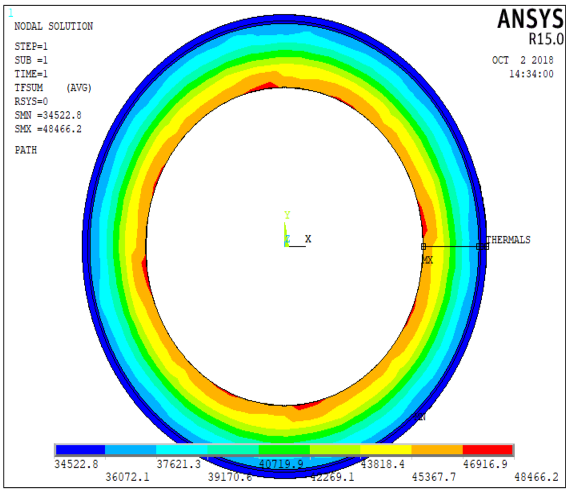

Fig 4.3 Silica Temperature Flux Distribution

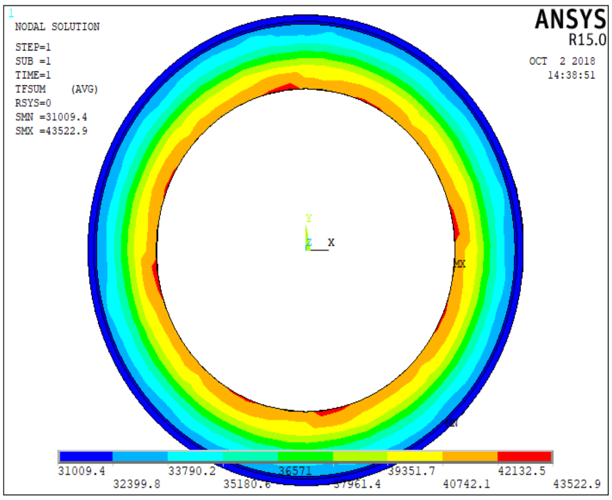

Fig 4.4 Zirconia Temperature Flux Distribution

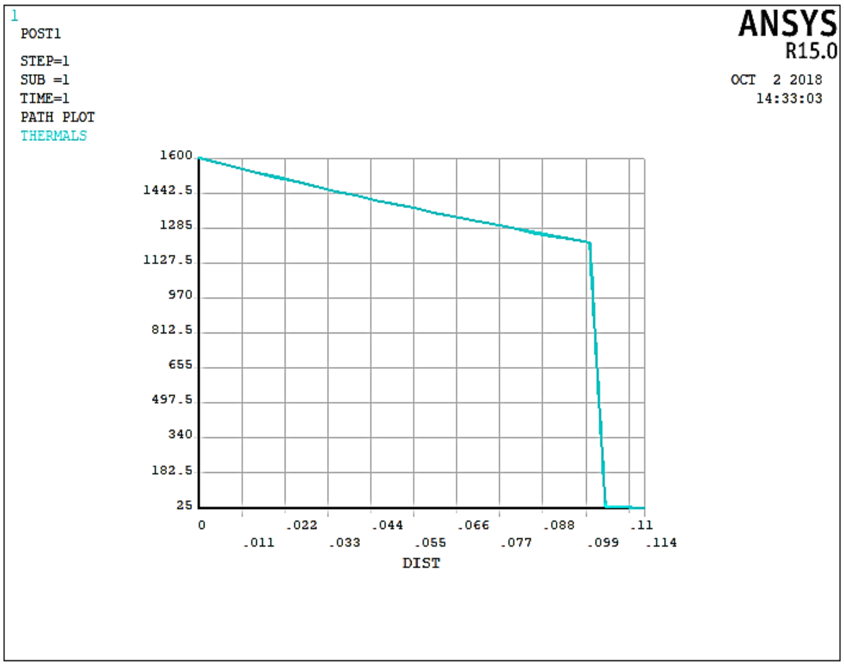

Fig 4.5 Silica Temperature Path Distribution from inner wall to outer wall

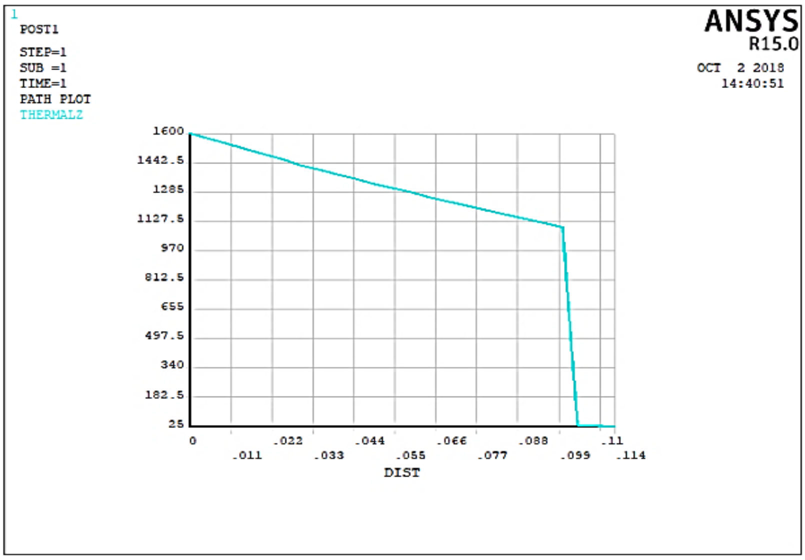

Fig 4.6 Zirconia Temperature Path Distribution from inner wall to outer wall

RESULTS AND CONCLUSION

ANSYS analysis shows that furnace lining with silica material temperature magnitude is 1161. If we use furnace lining with zirconia material temperature magnitude reduced to 1103 which is shown in Fig No.4.5and 4.6.That interprets the reduction with zirconium will be 5.2%. Similar trend observed by Prof. N.C. Mehta et al. [01] and Nihar P. Bara [02] this is because 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.

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