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OPTIMIZATION OF THICKNESS OF THE WALL USED IN HEAT TREATMENT FURNACE WITH DIFFERENT MATERIALS. (A CASE STUDY)

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Abstract
This paper focuses on the issue of minimum heat loss through the walls of heat treatment furnace by taking three materials namely chromite ,molybdenum and silica with respect to their thermal conductivity, wall thickness of the and area of the wall of respective material and compared by finding the best interaction of the these mechanical parameters with the use of Taguchi mathematical model of l9 orthogonal array with three levels of significance .By determining best interaction we could able to reduce 13 % to 30% of the heat loss which would have been evaluated without interchanging the parameters.
Keywords: Thermal conductivity, wall thickness, and area of the wall of heat furnace.

I. Introduction

A furnace is an equipment where an metals or non - metals can change the phases from solid to liquid to enable casting can soften the hard materials to enable rolling ,forging or change the mechanical properties to enable heat treatment.as flue gas is directly impinging with materials ,so the type of fuel selection is very important .like for induction furnace electricity is used ,for melting furnace fuel oil is used,for oil fired furnace , furnace oil is used and for ldo the sulphur is un desirable [1] .To increase the furnace efficiency the fuel must exibhit complete combustion. All the furnace are having the same components like

1 Refractory chamber
2 Hearth to support or carry shed
3. Chimney for removing exhaust gas
4. Burners for heating the fuel

5 .Charging and discharging doors through which the raw materials can be loaded and unloaded to obtain finished materials. Refractories is a material which can tolerate high temperature when it is in contact with very hot gas obtained due to burning of fuels, to heat the metals during heat treatment. It can also be able to absorb any sudden variation in temperatures inside the furnace. It is quite absorbent for abrasive forces and will not contaminate the material in contact with it.

Some important properties of refractories are:
1. Melting point – as refractory has to withstand high temperatures, so it is bonded with particles having high melting temperature. Size –To stabilize the furnace structure it is desired to keep exact fit of the refractory.
2. Bulk density – A bulk density is the amount of refractory material within a volume that as it increases, the volume stability, heat capacity and resistance to slag penetration [2]. Porosity – It is the volume of small tiny holes which is used for getting penetrated by liquid .A large number of small holes is desired in a Refractory.
3. Cold crushing strength –The cold crushing strength is the resistance to get crushed during movement. It indicates the abrasion resistance of the refractory.

4. Pyrometric cones equivalent- It is the cone which test the refractoriness of the bricks, when they are in contact with high temperature. So cones are the oxides which melt at elevated temperatures So they are put above the bricks and test is done to check which cones get bend and thus its behavior is noted.
5. Creep at high temperature – It determines the deformation in a given time and at given temperature under stress. Volume stability – Expansion and contraction at high temperatures might be changed due to changes in shape and size. Reversible Thermal expansion- There is always a changes in phase when it is heated or cooled .So it should posses reversible to expand or contract
6. Thermal conductivity- It is the mechanical parameter which prevents the loss of heat and is consist of chemical, mineralogical composition and silica. Depending on the type of operation like heat treatment, forging or casting there nature changes to find their application with respect to it.

Types of Refractories-
Refractories are classified on the basis of chemical composition, end use and methods of manufacture.
1.Fire clay refractories-its application is very wide in most of the iron and steel industry,non ferrous metallurgy, glass industry ,pottery kilns, cement industry and many others. Fire clay refractories such as fire bricks, siliceous fireclays and aluminum clay refractories consists of aluminum silicates with varying silica (SIO2) upto 78% and aluminum 44%.
2 High alumina refractories-In this refractories the aluminum composition is around 45 % so the function of refractoriness increases as aluminum contents increases.[3] Its wide application is blast furnace.cement kilns,ceramic kilns and pots for melting a huge range of metals.
3 Silica bricks – it is a refractory finds its wide application in iron and steel melting furnaces and glass industries as the silicon oxide percentage is 93%. The most important property of silica brick is that it does not begin to soften under high loads until its particles gets fused.
4 Magnesite – This type of refractories depend on the concentration of silicate bond at the elevated temperatures, which contains 85% MgO and also contains MgCo3 . Chromite refractories- This type of refractories are usually contains 15-35 % Cr2 O3 and 42-50 % MgO. This material can able to hold the elevated temperatures for corrosive slags and gases and have high refractoriness.
5. Zirconia refractories- This type of refractories needs a high degree of stabilization so it is treated with stabilizer with small quantities of calcium, magnesium and cerium oxide etc. It is having very low thermal conductivity so it finds application in high temperature insulating refractory. It is widely used in glass industry as it is not easily wetted by molten glasses [4]. Oxide refractories- Alumina refractories is also called oxide refractories as it contains aluminum oxide, which finds its wide application in melting crucibles for fusing sodium bicarbonate, sodium hydroxide and sodium peroxide. It can be operated at 18500 C. Monolithics- This are the single piece cast in the shape of ladle which are rapidly replacing the conventional type fired refractories in many applications including industrial furnaces.

II. Literature

Using FEA the optimization of wall thickness and the material to be used for wall has been analysed to determine minimum heat dissipation was surveyed by Mr Bhujbal Nitin, Prof S.B .Kumbhar [1] using melting iron, especially silica ramming mass as a refractory material. Analysis of combined heat transfer for a composite layer wall may consist of air as a layer acting as an insulator was surveyed by Armando Gallegos M Christian Violante C ,Jose A . Balderas B .Victor H. Rangel H. and Jose M. Belman F. [2] Here optimal thickness of multilayer was determined. Solution to solve the problems of induction furnace with the help of complex geometry were solved by A.A Bhatt, S .Agarwal, D .Sujish, B.Murlidharan, B.P Reddy, G. Padmakumar and K.K. Rajan [3] .Finally he studied on copper liner to reduce the electromagnetic coupling between the coil and the vessel to reduce it from getting overheated. The non steady state transfer of energy through a medium was analysed in an induction furnace with the help of finite element analysis was studied by Vipul Gondaliya ,Mehul Pujara, Niraj Mehta [4]. Optimization on wall thickness was evaluated by Nitesh T .mohite, Rvindra G.Benni [5] for evaluating the minimization of heat losses for induction furnace using the ramming masses of alumina ,magnesia and zirconia and compared his analysis with the Ansys workbench software and able to reduce 48% losses from properties and 64% from geometry. Determination of Refractory lining thickness of Steel plant mixer furnace by Istvan Szucs, prof. Dr . Tamas Koos [6] has aimed to elaborate a computational method where the actual thickness of the lining can be determined without the removal of the molten pig iron.

Problem Identification- Surveying from literature reviews it has been observed that many research has been carried out on the heat loss equation and thereby it is designed by finite analytical methods but none of them has determined the best interaction of mechanical parameters to get the performance evaluation with the same heat loss equation [7-8]. With deep investigation in our study a mathematical tool has to be implemented to evaluate the best interaction of the mechanical parameters. The famous mathematician Taguchi has designed several orthogonal array for various levels to establish a best

intermediate relationship between the mechanical parameters and thus it appeared successful in various use in engineering industries. Thus in our study we are going to select Orthogonal array of L9 with three significance levels .In our study the three levels are thermal conductivity ,wall thickness and area of slab where heat loss are to be determined inside the furnace.

III. Methodology and Result Discussions

Table 1 (a)Taguchi mathematical model L9 Orthogonal array with three significance levels table is shown below:

Cases/levels	**Level1**	**Level2**	**Level3**
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	2	3
7	3	1	3
8	3	2	1
9	3	3	2

(b) As our study is for determining the best interaction of thermal conductivity K, Wall thickness X and Area of the wall A so corresponding to above table our table for interaction will be-

Cases/Mechanical parameters	1=K	2=X	3=A
1	K_1	X_1	A_1
2	K_1	X_2	A_2
3	K_1	X_3	A_3
4	K_2	X_1	A_2
5	K_2	X_2	A_3
6	K_2	X_3	A_1
7	K_3	X_1	A_3
8	K_3	X_2	A_1
9	K_3	X_3	A_2

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2 . For determining above interaction we have to select various materials, values of their thermal conductivity, wall thickness, area of the wall and lining thickness with their thermal conductivity .Also the inside temperature of furnace and ambient temperature is known for heat treatment of steels.

Selection of materials for determining Heat loss-

1 Thermal conductivity:

(a) A= Chromium material whose thermal conductivity K1 =62.4 W/m0k at 9270celcius.

(b) B= Molybdenum material whose thermal conductivity K2 =105 W/m0k at 9270celcius.

(c) C= Silicon material whose thermal conductivity K3 =25.7 W/m0k at 9270celcius.

2 Wall thickness:

(a) X1= 170 mm=0.170 m (b) X2=175 mm=0.175 m (c) X3=180mm =0.180 m

3 Area of the wall inside the furnace: All the slabs are having the height of 110 mm. (a) A1 = 25 mm X 95 mm= 2.375X 10-3 m2

(b) A2 =30 mm X 95 mm=2.85 X 10-3 m2 (c) A3=35 mmX95mm=3.325X10-3 m2

4 Silica lining) is given for each an every slabs whose thickness =2" and their thermal conductivity =1.7 w/m0 k and this lining is adjoined with each of the slabs whose area is already selected in previous step.

5 From above datas we would calculate the values of heat transfer for each case and select the best interaction which will give the least heat loss value from table

6 The value which is obtained for minimum heat loss is in terms of watt ,which will be for one hour ,so we have to determine for 18 hour heat treatment work for 5 ton load of steel.

7.lastly we will plot the graph and evaluate the % save in power . Calculation:

1. Formula used:

From fourier law of heat transfer across the wall we have an equation

$$Q=-k.A.(T1-T2)/X$$

or $Q= - \{ (T1-T2) /X/KA\}$

or $Q= - \{ (T1-T2)/(X/K + XL/KL)$

Where symbol has the meanings as follows:

Q= Heat transfer across the wall in terms of Watt

T1= Temperature inside the furnace which is the maximum in terms of 0 kelvin T2= Temperature outside the furnace(ambient) in terms of 0 kelvin.

X= Wall thickness in terms of meters

K= Thermal conductivity in terms of W/m0 K

A=Area of the slab across which heat transfer takes place in terms of m2 Xl = Lining thickness in terms of meter

Kl = Thermal conductivity of silica lining in terms of W/m0 K

2. Evaluation of values and obtained the data of Q listed below:

Q	1	2	3	4	5	6	7	8	9
Values	64.6	78.0	90.0	80.2	93.5	66.7	80.8	57.4	68.5

3. Determination of best interaction: From above calculated data we conclude that 57.4 Watt gives the least heat loss values. Also this value represents for an hour ,further we have to calculate the 18 hour usage of watt for heat treatment of steel of 5 ton load capacity for a firm .The data for 18 hour heat loss is shown below:

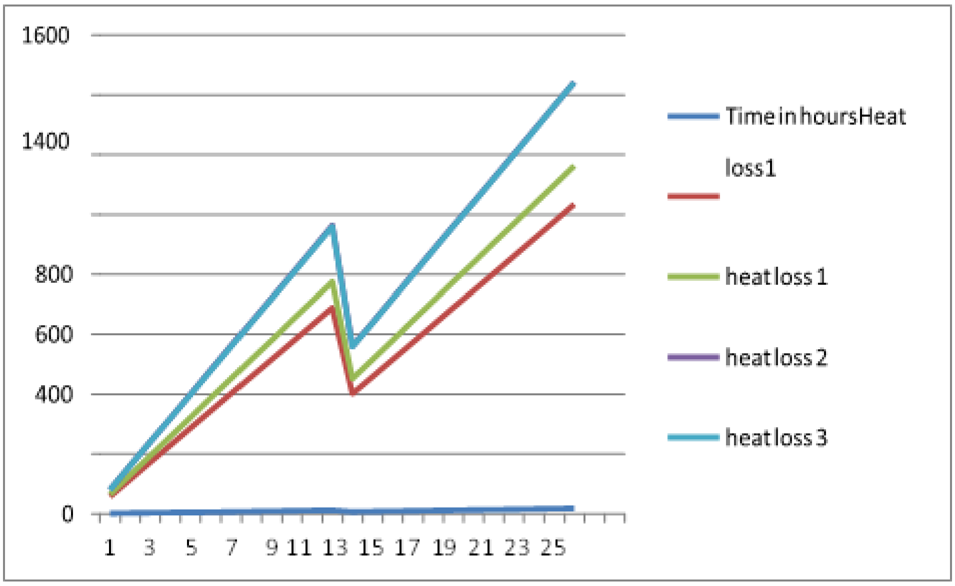
Time in terms of hour	Heat loss in watt	Time in terms of hour	Heat loss in watt
1	57.4	10	574
2	114.8	11	631.4
3	172.2	12	688.8
4	229.6	13	746.2
5	287	14	803.6
6	344.4	15	861
7	401.8	16	918.4
8	459.2	17	975.8
9	516.6	18	1033.2

Determination of heat loss for all thermal conductivities when we take the values individually like for k1 we will be considering X1 and A1.Similarly for K2 we will consider X2 and A2 and for K3 we will consider X3 and A3. There by we will calculate 18 hour data for each thermal conductivities and data is shown below.

Q1=64.6W Q2= 80.12 W Q3= 80.0W

Time in hours	Q1 for K1	Q2 for K2	Q3 for K3
1	64.6	80.12	80.0
2	129.2	160.2	160
3	193.8	240.3	240
4	258.4	320.4	320
5	323	401	400
6	387.6	481.4	480
7	452.2	560.7	560
8	516.8	640.96	640
9	581.4	721.08	720
10	646	801.2	800
11	710.6	881.32	880
12	775.2	961.4	960
13	839.8	1041.56	1040
14	904.4	1121.68	1120
15	969	1201.8	1200
16	1033.6	1281.92	1280
17	1098.2	1362.04	1362
18	1162.8	1442.16	1440

Graph: Graph (Figure 1) will be plotted against time in hours in abscissa and heat loss in ordinate as shown below: Graph is plotted between the best interaction values and Q1,Q2 and Q3 against time in hours.



IV. Conclusion

Conclusions :From above graph it is being observed that Q loss obtained from best interaction is having least heat loss as compared to other and thereby it saves about 13% to nearly 30% save if individualy heat loss is evaluated by taking them separately.

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