iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** II **Month of publication:** February 2020

DOI: http://doi.org/10.22214/ijraset.2020.2051

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 8 Issue II Feb 2020- Available at www.ijraset.com

FDM for Alumina based Induction Furnace Wall using Cylindrical Coordinate System

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Abstract: Furnaces are used for melting many materials like cast iron and steel for casting process. In this research paper, we had done Finite Difference Modelling of Induction melting furnace refractory wall made of alumina ramming mass using cylindrical coordinate system. We have divided actual geometry of furnace refractory wall into 14 elements and 24 nodes. We have derived explicit finite difference equations for all 24 nodes. We have calculated temperature distribution and thermal stress distribution for all different nodes with respect to time. We have plotted graphs for maximum temperature v/s time and maximum stress v/s time. We found that results indicate the effect of thermal fatigue in the induction furnace wall for alumina ramming mass. The analysis is very helpful in understanding how thermal fatigue failure of refractory wall happens.
Key words: Cylindrical Coordinate System, Temperature distribution, Stress distribution, Finite Difference Model

I. INRODUCTION

Furnace is a term used to identify a closed space where heat is applied to a body in order to raise its temperature. The source of heat may be fuel or electricity. Commonly, metals and alloys and sometimes non-metals are heated or melted in furnaces. The purpose of heating defines the temperature of heating and heating rate. Increase in temperature softens the metals. They become amenable to distortion. This relaxing occurs with or without a change in the metallic structure. Heating to lower temperatures (below the critical temperature) of the metal softens it by relieving the internal stresses. On the other hand, metals heated to temperatures above the critical temperatures leads to changes in crystal structures and recrystallization like annealing. Further some metals and alloys are melted, ceramic products vitrified, coals coked, metals like zinc are vaporized and many other processes are completed in Furnaces.

Induction melting and heating furnaces are widely used in the iron industry and steel industry for the casting of the different grades of cast iron products. Refractory wall of induction melting furnace is a key component which is used as insulation layer. It is made of ramming mass like silica, alumina, magnesia etc. The refractory wall is directly influenced by the thermal cycling of the high temperature molten iron in the furnace. Thermal fatigue failure is easy to happen for it because of the larger phase transformation thermal stresses and it has a shorter life. This can cause serious production accidents. Therefore, the service life problem of the refractory wall has always been a focus of attention in the application of this to the industry.

The research on the distribution of temperature and thermal stress with respect to time for the refractory wall will not only put foundation for the investigation on the thermal fatigue of this kind of parts under thermal fatigue condition of low cycle and high phase transition stresses but also offers effective control for thermal fatigue failure and provide basis for improvement of life span of these kind of parts.

Computational heat transfer, computational fluid dynamic analysis is done for induction melting furnace, refrigerator condenser, induction heating furnace using different numerical methods like finite volume method and finite element method by different researchers.

Here, Explicit Finite Difference Method is used to find out temperature and thermal stress variation with respect to time.

II. DEVELOPMENT OF FINITE DIFFERENCE MODEL

We have divided Induction Furnace Wall into a Nodal Network as shown in Fig. 1. It is divided into 24 nodes. We have derived Explicit Finite Difference Equations for all nodes as per the boundary conditions applied to it. The furnace wall is having thermal conduction heat transfer between different nodes. It is having atmospheric heat convection ha applied from top side of the furnace wall which is open to atmosphere. It is having heat convection from molten metal from inside which is hi. It is having heat convection ho from cooling water which is circulating outside the furnace wall.

To solve this advanced heat transfer problem of induction melting furnace wall which is made from Alumina Ramming Mass, the following initial and boundary conditions, material properties and basic assumptions are made:

A. Refractory Materials for induction melting furnace wall meets the basic assumptions in the science of mechanics.
B. Environmental Air Temperature is homogeneous at 27° C.
C. Ignore the influence of heat radiation.
D. Ignore the effect of gravity field on wall.
E. The surface of induction melting furnace wall is clean and clear.
F. The initial temperature of the induction melting furnace is set 27° C and it is agreement with the ambient temperature during solving the problem.
G. Heat convections from air, cooling water and molten metal are considered constant for this analysis.
H. Scarp raw material input inside furnace is considered uniform for our analysis.

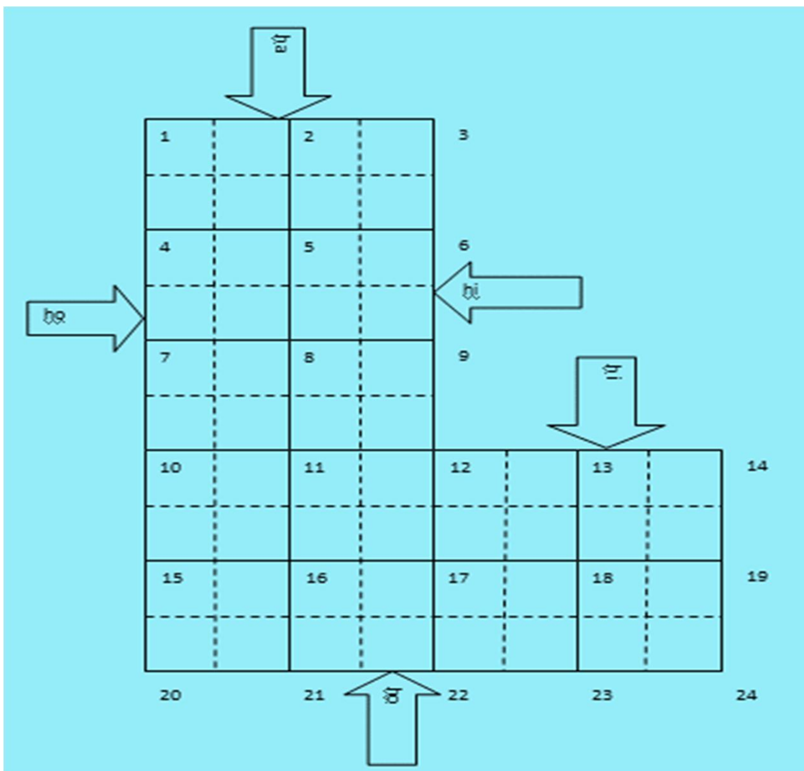

Fig.1. Nodal network for finite difference method

1) NODE: -1

$$T_1^{i+1}=\left(\left(h_a\frac{\Delta x}{2}(T_\infty-T_1^i)+h_o\frac{\Delta y}{2}(T_\infty-T_1^i)+\pi k\Delta y\frac{T_2^i-T_1^i}{\ln\left(\frac{r_1}{r_2}\right)}+k\frac{\Delta x}{2}\frac{T_4^i-T_1^i}{\Delta y}\right)\frac{4\Delta t}{\rho C\Delta x\Delta y}\right)+T_1^i$$

T [1][i+1] = (((0.5*h $_a$*x*(T$_o$– T[1][i])) + (h$_o$*y*(T$_a$– T[1][i]/2) +(π*k*y*(T[2][i]-T[1][i])/ln(r_1/r$_2$)) +(0.5*k*x*(T[4][i]-T[1][i]/y))*((4*t)/(r*c*x*y)))+T[1][i];

2) NODE:-2

$$T_2^{i+1}=\left(\left(h_a\Delta x(T_\infty-T_2^i)+\pi k\Delta y\frac{T_1^i-T_2^i}{\ln\left(\frac{r_1}{r_2}\right)}+\pi k\Delta y\frac{T_3^i-T_2^i}{\ln\left(\frac{r_2}{r_3}\right)}+k\Delta x\frac{T_5^i-T_2^i}{\Delta y}\right)\frac{2\Delta t}{\rho C\Delta x\Delta y}\right)+T_2^i$$

T[2][i+1]=(((h $_a$ *x*(T$_o$ – T[2][i]))+(π*k*y*(T[1][i]-T[2][i])/ln(r_1/r$_2$)+(π*k*Y*T[3][i]-T[2][i]/ In(r_2/r$_3$)+k*x*(T[5][i]-T[2][i])/y))*((2*t)/(r*c*x*y)))+T[2][i];

3) NODE:-3

$$T_3^{i+1} = \left(h_a \frac{\Delta x}{2}(T_\infty - T_3^i) + h_i \frac{\Delta y}{2}(T_h - T_3^i) + \pi k \Delta y \frac{T_2^i - T_3^i}{\ln\left(\frac{r_2}{r_3}\right)} + k \frac{\Delta x}{2} \frac{T_6^i - T_3^i}{\Delta y}\right) \frac{4\Delta t}{\rho C \Delta x \Delta y}\Big) + T_3^i$$

T [3][i+1] = (((h $_a$*x*(T$_o$ – T[3][i]*0.5) + (h$_i$ *y*(T$_h$ - T[3][i]*0.5)+(0.5*k*x*(T[6][i]-T[3][i]/y)+(π*k*y*(T[2][i]-T[3][i])/ln(r_2/r$_3$)))*((4*t)/(r*c*x*y)))+T[3][i];

4) NODE:-4

$$T_4^{i+4} = \left(h_o \Delta y \, (T_\infty - T_4^i) + \pi k \Delta y \frac{T_5^i - T_4^i}{\ln\left(\frac{r_1}{r_2}\right)} + k \frac{\Delta x}{2} \frac{T_1^i - T_4^i}{\Delta y} + k \frac{\Delta x}{2} \frac{T_7^i - T_4^i}{\Delta y}\right) \frac{2\Delta t}{\rho C \Delta x \Delta y}\Big) + T_4^i$$

T [4][i+1] = (((h $_o$ *y*(T$_a$– T[4][i])) + (π*k*y*(T[5][i]-T[4][i])/ln(r_1/r$_2$)) + (0.5*k*x*(T[1][i]-T[4][i]/y) + (0.5*k*x*(T[7][i]-T[4][i])/y))*((2*t)/(r*c*x*y)))+T[4][i];

5) NODE:-5

$$T_5^{i+1} = \left(\left(\pi k \Delta y \frac{T_4^i - T_5^i}{\ln\left(\frac{r_1}{r_2}\right)} + \pi k \Delta y \frac{T_6^i - T_5^i}{\ln\left(\frac{r_2}{r_3}\right)} + k\Delta x \frac{T_2^i - T_5^i}{\Delta y} + k\Delta x \frac{T_8^i - T_5^i}{\Delta y}\right) \frac{\Delta t}{\rho C \Delta x \Delta y}\right) + T_5^i$$

T [5][i+1] = (((π*k*y*(T[4][i]-T[5][i])/ln(r_1/r$_2$)) + (π*k*y*(T[6][i]-T[5][i])/ln(r_2/r$_3$)) +(k*x*(T[2][i]-T[5][i]/y) +(k*x*(T[8][i]-T[5][i]/y))*((t)/(r*c*x*y)))+T[5][i];

6) NODE:-6

$$T_6^{i+1} = \left(\left(h_i \Delta y \, (T_h - T_6^i) + \pi k \Delta y \frac{T_5^i - T_6^i}{\ln\left(\frac{r_2}{r_3}\right)} + k \frac{\Delta x}{2} \frac{T_3^i - T_6^i}{\Delta y} + k \frac{\Delta x}{2} \frac{T_9^i - T_6^i}{\Delta y}\right) \frac{2\Delta t}{\rho C \Delta x \Delta y}\right) + T_6^i$$

T [6][i+1] = (((h $_i$*y*(T$_h$– T[6][i])) + (π*k*y*(T[5][i]-T[6][i])/ln(r_2/r$_3$)) + (0.5*x*k*(T[3][i]-T[6][i]/y) + (0.5*k*x*(T[9][i]-T[6][i])/y))*((2*t)/(r*c*x*y)))+T[6][i];

7) NODE:-7

$$T_7^{i+7} = \left(\left(h_o \Delta y \, (T_\infty - T_7^i) + \pi k \Delta y \frac{T_8^i - T_7^i}{\ln\left(\frac{r_1}{r_2}\right)} + k \frac{\Delta x}{2} \frac{T_4^i - T_7^i}{\Delta y} + k \frac{\Delta x}{2} \frac{T_{10}^i - T_7^i}{\Delta y}\right) \frac{2\Delta t}{\rho C \Delta x \Delta y}\right) + T_7^i$$

T [7][i+1] = (((h $_o$*y*(T$_a$– T[7][i])) + (π*k*y*(T[8][i]-T[7][i])/ln(r_1/r$_2$) + (k*0.5*x*(T[4][i]-T[7][i]/y) + (0.5*k*x*(T[10][i]-T[7][i])/y))*((2*t)/(r*c*x*y)))+T[7][i];

8) NODE:-8

$$T_8^{i+1} = \left(\left(\pi k \Delta y \frac{T_7^i - T_8^i}{\ln\left(\frac{r_1}{r_2}\right)} + \pi k \Delta y \frac{T_9^i - T_8^i}{\ln\left(\frac{r_2}{r_3}\right)} + k \Delta x \frac{T_5^i - T_8^i}{\Delta y} + k \Delta x \frac{T_{11}^i - T_8^i}{\Delta y}\right) \frac{\Delta t}{\rho C \Delta x \Delta y}\right) + T_8^i$$

T [8][i+1] = (((π*k*y*(T[7][i]-T[8][i])/ln(r_1/r$_2$)) +(π*k*y*(T[9][i]-T[8][i])/ln(r_2/r$_3$)) +(k*x*(T[5][i]-T[8][i])/y) + (k*x*(T[11][i]-T[8][i])/y)) *((t)/(r*c*x*y)))+T[8][i];

9) NODE:-9

$$T_9^{i+1} = \left(\left(h_i \Delta y \, (T_h - T_9^i) + \pi k \Delta y \frac{T_8^i - T_9^i}{\ln\left(\frac{r_2}{r_3}\right)} + k \frac{\Delta x}{2} \frac{T_6^i - T_9^i}{\Delta y} + k \frac{\Delta x}{2} \frac{T_{12}^i - T_9^i}{\Delta y}\right) \frac{2\Delta t}{\rho C \Delta x \Delta y}\right) + T_9^i$$

T [9][i+1] = ((h$_i$*y*(T$_h$– T[9][i])) + (π*k*y*(T[8][i]-T[9][i])/ln(r_2/r$_3$)) + (k*0.5*x*(T[6][i]-T[9][i]/y) + (0.5*k*x*(T[12][i]-T[9][i])/y))*((2*t)/(r*c*x*y)))+T[9][i];

10) NODE:-10

$T_{10}^{i+10} = \left(\left(h_o\Delta y\,(T_\infty - T_{10}^{i}) + \pi k\Delta y\frac{T_{11}^{i}-T_{10}^{i}}{\ln\left(\frac{r_1}{r_2}\right)} + k\frac{\Delta x}{2}\frac{T_7^{i}-T_{10}^{i}}{\Delta y} + k\frac{\Delta x}{2}\frac{T_{15}^{i}-T_{10}^{i}}{\Delta y}\right)\frac{2\Delta t}{\rho C\Delta x\Delta y}\right) + T_{10}^{i}$

T [10][i+1] = (((h_o*y*(T_a– T[10][i])) + (π*k*y*(T[11][i]-T[10][i])/ln(r_1/r_2)) + (0.5*k*x*(T[7][i]-T[10][i]/y) + (0.5*k*x*(T[15][i]-T[10][i])/y))*((2*t)/(r*c*x*y)))+T[10][i];

11) NODE:-11

$T_{11}^{i+1} = \left(\left(\pi k\,\Delta y\frac{T_{10}^{i}-T_{11}^{i}}{\ln\left(\frac{r_1}{r_2}\right)} + \pi k\Delta y\frac{T_{12}^{i}-T_{11}^{i}}{\ln\left(\frac{r_2}{r_3}\right)} + k\Delta x\frac{T_8^{i}-T_{11}^{i}}{\Delta y} + k\Delta x\frac{T_{16}^{i}-T_{11}^{i}}{\Delta y}\right)\frac{\Delta t}{\rho C\Delta x\Delta y}\right) + T_{11}^{i}$

T [11][i+1] = ((π*k*y*(T[10][i]-T[11][i])/ln(r_1/r_2)) + (π*k*y*(T[12][i]-T[11][i])/ln(r_2/r_3)) + (k*x*(T[8][i]-T[11][i])/y) + (k*x*(T[16][i]-T[11][i])/y))*((t)/(r*c*x*y)))+T[11][i];

12) NODE:-12

$T_{12}^{i+1} = \left(\left(h_i\frac{\Delta x}{2}(T_h - T_{12}^{i}) + h_i\frac{\Delta y}{2}(T_h - T_{12}^{i}) + \pi k\Delta y\frac{T_{11}^{i}-T_{12}^{i}}{\ln\left(\frac{r_2}{r_3}\right)} + \pi k\Delta y\frac{T_{13}^{i}-T_{12}^{i}}{\ln\left(\frac{r_3}{r_4}\right)} + k\frac{\Delta x}{2}\frac{T_9^{i}-T_{12}^{i}}{\Delta y} + k\Delta x\frac{T_{17}^{i}-T_{12}^{i}}{\Delta y}\right)\frac{4\Delta t}{\rho C\Delta x\Delta y}\right) + T_{12}^{i}$

T [12][i+1] = (((0.5*h_i*x*(T_h– T[12][i])) + (0.5*h_i*y*(T_h– T[12][i])) + (π*k*y*(T[11][i]-T[12][i])/ln(r_2/r_3)) +(π*k*y*(T[13][i]-T[12][i])/ln(r_3/r_4)) + (0.5*k*x*(T[9][i]-T[12][i])/y) + (k*x*(T[17][i]-T[12][i])/y)*((4*t)/(3*r*c*x*y)))+T[12][i];

13) NODE:-13

$T_{13}^{i+1} = \left(\left(h_i\Delta x\,(T_h - T_{13}^{i}) + \pi k\Delta y\frac{T_{12}^{i}-T_{13}^{i}}{\ln\left(\frac{r_3}{r_4}\right)} + \pi k\Delta y\frac{T_{14}^{i}-T_{13}^{i}}{\ln\left(\frac{r_4}{r_5}\right)} + k\Delta x\frac{T_{18}^{i}-T_{13}^{i}}{\Delta y}\right)\frac{2\Delta t}{\rho C\Delta x\Delta y}\right) + T_{13}^{i}$

T [13][i+1] = ((h_i*x*(T_h– T[13][i])) + (π*k*y*(T[12][i]-T[13][i])/ln(r_3/r_4)) + (π*k*y*(T[14][i]-T[13][i])/ln(r_4/r_5)) + (k*x*(T[18][i]-T[13][i]/y)*((2*t)/(r*c*x*y)))+T[13][i];

14) NODE:-14

$T_{14}^{i+1} = \left(\left(h_i\frac{\Delta x}{2}(T_h - T_{14}^{i}) + h_i\frac{\Delta y}{2}(T_h - T_{14}^{i}) + \pi k\Delta y\frac{T_{13}^{i}-T_{14}^{i}}{\ln\left(\frac{r_4}{r_5}\right)} + k\frac{\Delta x}{2}\frac{T_{19}^{i}-T_{14}^{i}}{\Delta y}\right)\frac{4\Delta t}{\rho C\Delta x\Delta y}\right) + T_{14}^{i}$

T [14][i+1] = ((0.5*h_i*x*(T_h– T[14][i])) +(0.5*h_i*y*(T_h– T[14][i])) + (π*k*y*(T[13][i]-T[14][i])/ln(r_4/r_5)) + (k*0.5*x*(T[19][i]-T[14][i]/y))*((4*t)/(r*c*x*y)))+T[14][i];

15) NODE:-15

$T_{15}^{i+15} = \left(\left(h_o\Delta y\,(T_\infty - T_{15}^{i}) + \pi k\Delta y\frac{T_{16}^{i}-T_{15}^{i}}{\ln\left(\frac{r_1}{r_2}\right)} + k\frac{\Delta x}{2}\frac{T_{10}^{i}-T_{15}^{i}}{\Delta y} + k\frac{\Delta x}{2}\frac{T_{20}^{i}-T_{15}^{i}}{\Delta y}\right)\frac{2\Delta t}{\rho C\Delta x\Delta y}\right) + T_{15}^{i}$

T [15][i+1] = (((h_o*y*(T_a– T[15][i])) + (π*k*y*(T[16][i]-T[15][i])/ln(r_1/r_2)) + (0.5*k*x*(T[10][i]-T[15][i]/y) + (0.5*k*x*(T[20][i]-T[15][i])/y))*((2*t)/(r*c*x*y)))+T[15][i];

16) NODE:-16

$T_{16}^{i+1} = \left(\left(\pi k\,\Delta y\frac{T_{15}^{i}-T_{16}^{i}}{\ln\left(\frac{r_1}{r_2}\right)} + \pi k\Delta y\frac{T_{17}^{i}-T_{16}^{i}}{\ln\left(\frac{r_2}{r_3}\right)} + k\Delta x\frac{T_{11}^{i}-T_{16}^{i}}{\Delta y} + k\Delta x\frac{T_{21}^{i}-T_{16}^{i}}{\Delta y}\right)\frac{\Delta t}{\rho C\Delta x\Delta y}\right) + T_{16}^{i}$ T [16][i+1] = ((π*k*y*(T[15][i]-T[16][i])/ln(r_1/r_2)) + (π*k*y*(T[17][i]-T[16][i])/ln(r_2/r_3)) + (k*x*(T[11][i]-T[16][i])/y) + (k*x*(T[21][i]-T[16][i])/y))*((t)/(r*c*x*y)))+T[16][i];

17) NODE:-17

$$T_{17}^{i+1} = \left(\left(\pi k\Delta y\frac{T_{16}^i - T_{17}^i}{\ln\left(\frac{r_2}{r_3}\right)} + \pi k\Delta y\frac{T_{18}^i - T_{17}^i}{\ln\left(\frac{r_3}{r_4}\right)} + k\Delta x\frac{T_{12}^i - T_{17}^i}{\Delta y} + k\Delta x\frac{T_{22}^i - T_{17}^i}{\Delta y}\right)\frac{\Delta t}{\rho C\Delta x\Delta y}\right) + T_{17}^i$$

T [17][i+1] = ((π*k*y*(T[16][i]-T[17][i])/ln(r_2/r$_3$)) +(π*k*y*(T[18][i]-T[17][i])/ln(r_3/r$_4$)) + (k*x*(T[12][i]-T[17][i])/y) + (k*x*(T[22][i]-T[17][i])/y))*((t)/(r*c*x*y)))+T[17][i];

18) NODE:-18

$$T_{18}^{i+1} = \left(\left(\pi k\Delta y\frac{T_{17}^i - T_{18}^i}{\ln\left(\frac{r_3}{r_4}\right)} + \pi k\Delta y\frac{T_{19}^i - T_{18}^i}{\ln\left(\frac{r_4}{r_5}\right)} + k\Delta x\frac{T_{13}^i - T_{18}^i}{\Delta y} + k\Delta x\frac{T_{23}^i - T_{18}^i}{\Delta y}\right)\frac{\Delta t}{\rho C\Delta x\Delta y}\right) + T_{18}^i$$

T [18][i+1] = ((π*k*y*(T[17][i]-T[18][i])/ln(r_3/r$_4$)) + (π*k*y*(T[19][i]-T[18][i])/ln(r_4/r$_5$)) + (k*x*(T[13][i]-T[18][i]/y) +(k*x*(T[23][i]-T[18][i]/y) *((t)/(r*c*x*y)))+T[18][i];

19) NODE:-19

$$T_{19}^{i+1} = \left(\left(h_i\Delta y\,(T_h - T_{19}^i) + \pi k\Delta y\frac{T_{18}^i - T_{19}^i}{\ln\left(\frac{r_4}{r_5}\right)} + k\frac{\Delta x}{2}\frac{T_{14}^i - T_{19}^i}{\Delta y} + k\frac{\Delta x}{2}\frac{T_{24}^i - T_{19}^i}{\Delta y}\right)\frac{2\Delta t}{\rho C\Delta x\Delta y}\right) + T_{19}^i$$

T [19][i+1] = ((h_i*y*(T_h– T[19][i])) + (π*k*y*(T[18][i]-T[19][i])/ln(r_4/r$_5$)) + (k*0.5*x*(T[14][i]-T[19][i]/y) + (0.5*k*x*(T[24][i]-T[19][i]/y))*((2*t)/(r*c*x*y)))+T[19][i];

20) NODE:-20

$$T_{20}^{i+20} = \left(\left(h_o\frac{\Delta x}{2}\,(T_\infty - T_{20}^i) + \left(h_o\frac{\Delta y}{2}\,(T_\infty - T_{20}^i\right) + \pi k\Delta y\frac{T_{21}^i - T_{20}^i}{\ln\left(\frac{r_1}{r_2}\right)} + k\frac{\Delta x}{2}\frac{T_{15}^i - T_{20}^i}{\Delta y}\right)\frac{4\Delta t}{\rho C\Delta x\Delta y}\right) + T_{20}^i$$

T [20][i+1] = (((0.5*h $_o$*x*(T_a– T[20][i])) + (0.5*h_o*y*(T_a– T[20][i])) +(π*k*y*(T[21][i]-T[20][i])/ln(r_1/r$_2$)) +(0.5*x*k*(T[15][i]-T[20][i]/y))*((4*t)/(r*c*x*y)))+T[20][i];

21) NODE:-21

$$T_{21}^{i+1} = \left(\left(h_o\Delta x\,(T_\infty - T_{21}^i) + \pi k\Delta y\frac{T_{20}^i - T_{21}^i}{\ln\left(\frac{r_1}{r_2}\right)} + \pi k\Delta y\frac{T_{22}^i - T_{21}^i}{\ln\left(\frac{r_2}{r_3}\right)} + k\Delta x\frac{T_{16}^i - T_{21}^i}{\Delta y}\right)\frac{2\Delta t}{\rho C\Delta x\Delta y}\right) + T_{21}^i$$

T [21][i+1] = ((h_o*x*(T_a– T[21][i])) + (π*k*y*(T[20][i]-T[21][i])/ln(r_1/r$_2$)) + (π*k*y*(T[22][i]-T[21][i])/ln(r_2/r$_3$)) + (k*x*(T[16][i]-T[21][i]/y))*((2*t)/(r*c*x*y)))+T[21][i];

22) NODE:-22

$$T_{22}^{i+1} = \left(\left(h_o\Delta x\,(T_\infty - T_{22}^i) + \pi k\Delta y\frac{T_{21}^i - T_{22}^i}{\ln\left(\frac{r_2}{r_3}\right)} + \pi k\Delta y\frac{T_{23}^i - T_{22}^i}{\ln\left(\frac{r_3}{r_4}\right)} + k\Delta x\frac{T_{17}^i - T_{23}^i}{\Delta y}\right)\frac{2\Delta t}{\rho C\Delta x\Delta y}\right) + T_{22}^i$$

T [22][i+1] = ((h_o*x*(T_a– T[22][i])) + (π*k*y*(T[21][i]-T[22][i])/ln(r_3/r$_4$)) + (π*k*y*(T[23][i]-T[22][i])/ln(r_4/r$_5$)) + (k*x*(T[17][i]-T[22][i]/y))*((2*t)/(r*c*x*y)))+T[22][i];

23) NODE:-23

$$T_{23}^{i+1} = \left(\left(h_o\Delta x\,(T_\infty - T_{23}^i) + \pi k\Delta y\frac{T_{22}^i - T_{23}^i}{\ln\left(\frac{r_3}{r_4}\right)} + \pi k\Delta y\frac{T_{24}^i - T_{23}^i}{\ln\left(\frac{r_4}{r_5}\right)} + k\Delta x\frac{T_{18}^i - T_{23}^i}{\Delta y}\right)\frac{2\Delta t}{\rho C\Delta x\Delta y}\right) + T_{23}^i$$

T [23][i+1] = ((h_o*x*(T_a– T[23][i])) + (π*k*y*(T[22][i]-T[23][i])/ln(r_3/r$_4$)) + (π*k*y*(T[24][i]-T[23][i])/ln(r_4/r$_5$)) + (k*x*(T[18][i]-T[23][i]/y))*((2*t)/(r*c*x*y)))+T[23][i];

24) NODE:-24

$$T_{24}^{i+1} = \left(\left(h_o\frac{\Delta x}{2}(T_\infty - T_{24}^{i}) + h_i\frac{\Delta y}{2}(T_h - T_{24}^{i}) + \pi k\Delta y\frac{T_{23}^{i} - T_{24}^{i}}{\ln\left(\frac{r_4}{r_5}\right)} + k\frac{\Delta x}{2}\frac{T_{19}^{i} - T_{24}^{i}}{\Delta y}\right)\frac{4\Delta t}{\rho C\Delta x\Delta y}\right) + T_{24}^{i}$$

T [24][i+1] = (((0.5*h o*x*(T_a– T[24][i])) + (0.5*h_i*y*(T_h– T[24][i])) +(π*k*y*(T[23][i]-T[24][i])/ln(r_4/r_5)) +(0.5*k*x*(T[19][i]-T[24][i]/y))*((4*t)/(r*c*x*y)))+T[24][i];

III. PROGRAMMING & SOLUTION

With the help of a computer program we can solve the matrix created by finite difference equations for 24 nodes. We are using material properties and boundary conditions as given in Table 1. We can calculate temperature distribution and stress distribution with respect to time.

Table 1. Material Property and Boundary Conditions

Material Properties and Boundary Conditions for Silica Ramming Mass			Unit
1	Internal Film Co-efficient hi	200	W/m^2 K
2	External Film Co-efficient ho	40	W/m^2 K
3	Atmosphere Film Co-efficient ha	10	W/m^2 K
4	Density	3400	Kg/m^3
5	Time Interval Δt	10	Seconds
6	Thermal Conductivity k	2.6	W/m K
7	Temperature outside Furnace Wall	303	Kelvin
8	Temperature inside Furnace Wall	1873	Kelvin
9	Temperature of Air	303	Kelvin
10	Specific Heat	920	J/kg K
11	Elasticity Constant	220000	N/ m^2
12	Thermal Expansion Co-efficient	0.00000088	m/ K
13	Ultimate Stress	500	MPa

IV. RESULTS AND DISCUSSION

We can see from the Fig. 2 that maximum temperature is increasing from atmospheric temperature 300 K and reaches to maximum temperature 1787 K in 45 minutes and then starts reducing and reaches to 869 K in next 15 minutes. It again starts increasing and reaches to maximum 1787 K after 105 minutes and again starts reducing. There are 10 similar temperature cycles in one day.

We can see from the Fig. 3 that maximum thermal stress is increasing from initial condition 0 MPa and reaches to maximum stress 346 MPa in 45 minutes and then starts reducing and reaches to 168 MPa in next 15 minutes. It again starts increasing and reaches to maximum stress 346 MPa after 105 minutes and again it starts reducing. There are 10 similar thermal stress cycles in one day.

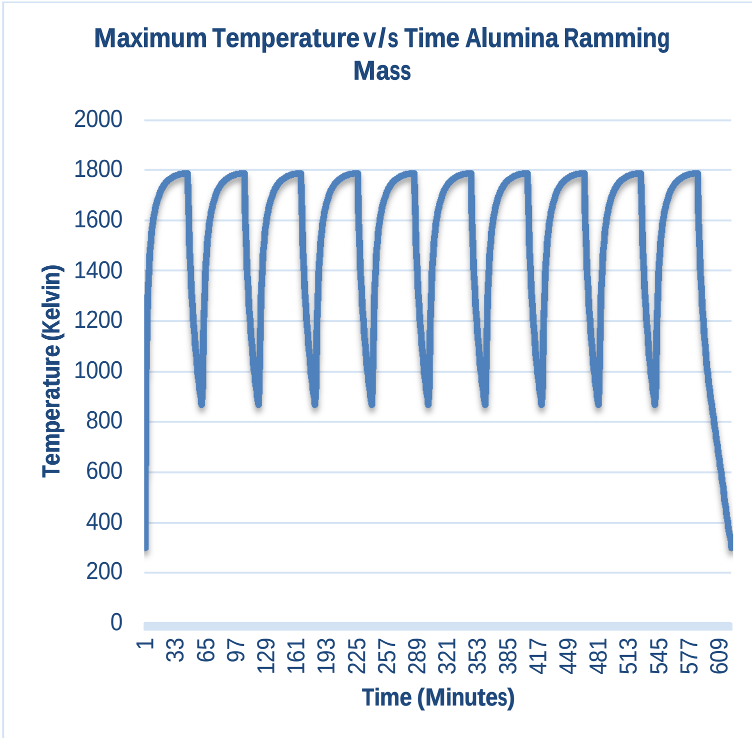

Fig. 2. Maximum Temperature v/s Time Graph for Alumina Ramming Mass

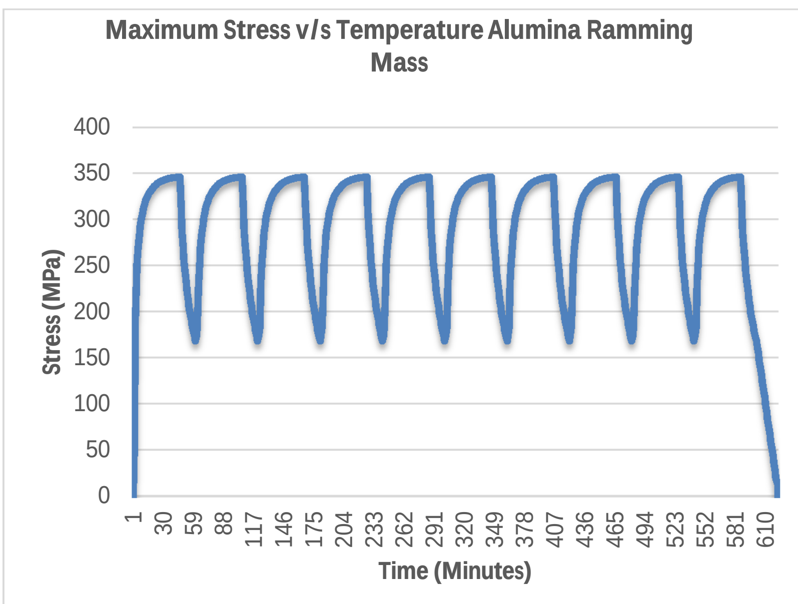

Fig. 3. Maximum Thermal Stress v/s Time Plot for Alumina Ramming Mass

V. CONCLUSION

Induction melting furnaces are highly used now- a-days for melting of different kinds of materials. We have found variation of maximum temperature and maximum stress with reference to time. From the graph, we can conclude that induction furnace wall which is made from alumina ramming mas is under the effect of low cycle thermal fatigue. The reason for its low life span is thermal fatigue behavior of its loading conditions.

VI. FUTURE SCOPE

This analysis can be utilized for prediction of life cycle of induction furnace wall which is made up of alumina based refractory materials. It can also be utilized to improve efficacy of furnace and optimization of wall thickness.

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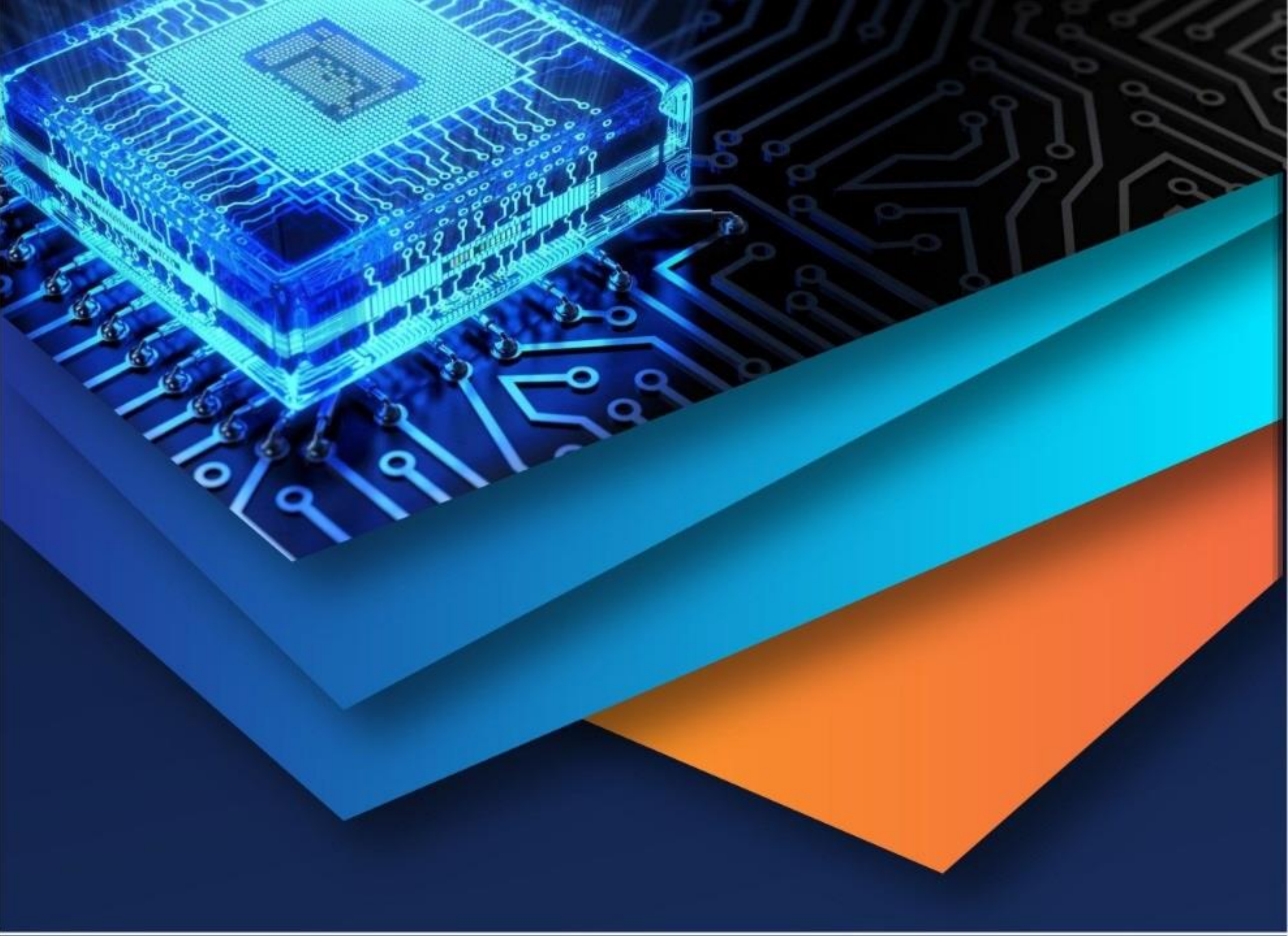

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