Development of Mathematical Model for Heat Transfer Analysis of Cylindrical Induction Furnace Wall

[1]Patil Kaushal, [2]Arab Mohammadazhar, [3]Makwana Arjunsinh,

[1,2,3]*Students, Vadodara Institute of Engineering, Vadodara, Gujarat, India*

ABSTRACT

Furnace are most almost continuously used for melting of materials. Induction Cylindrical and spherical furnaces are more invaluable as no fuel is required. The purpose of the furnaces is to chemically reduce and physically convert iron oxides into liquid iron it is called as hot metal. Handling of furnace unit is not simple issue. It is a difficulty to search out life cycle of Induction type cylindrical furnace wall beneath load variant. The Induction type cylindrical furnace wall is made-up of silica ramming mass by experimental study which is one variety of refractory material. During the furnace operation various hazards like fire and explosion, furnace gases is more hazardous and explosive in a nature arise. The issue of induction type cylindrical furnace wall loses its properties after some cycles and hours. The problem comes from this Induction type cylindrical furnace is losing its life cycle and disturb production schedule in industries so we needed proper life span of the furnaces. The failure happens because of cyclic thermal stress due to heating and cooling cycle in furnaces. The problem of these furnaces will occur by computational heat transfer analysis by mathematically method. It is explicit finite difference analysis method. We also work on modification and the area of efficiency, cost, material used in furnace and analysis by mathematically solution. We made mathematical model on Turbo C^{++} software and analysis of cylindrical induction furnace. By which we have find life cycle of furnace wall with various types of refractory materials used making furnace wall. We found forecasting life span of cylindrical and furnace by used of finite difference method and divided in nodes. We are plotted output values on stress v/s life cycle graph.

Key words: *Mathematically, Advanced Heat Transfer, Induction Furnace Wall, Cylindrical Furnace, silica ramming mass.*

I. INTRODUCTION

The furnace is an equipment to use for melt the metals for casting or heating of material to changing shape and size like rolling, forging etc. It is also used for change the properties of the metals like heat treatment processes. Generally, furnace is classified into two types according to generating method of heat. It is combustion type and electric type. In combustion type furnace generally used as fuel is oil and coal. Then electric type furnace called as induction furnace. These are generally used in automobile and melting scrap industries.

If we want to solving problem of simple heat transfer involving simple geometries with simple boundary condition. It is solved by analytical method but, when it wills complex boundary condition than we cannot solved analytically. There are several ways of obtains the numerical formulation of heat transfer problem such as finite difference method, finite element method, boundary element method.

II. DEVELOPMENT OF ADVANCED EXPLICT DIFFERENCE MODEL.

The cylindrical induction furnace wall divided into nodal network is in Fig.1.it is divided into 24 nodes and various radius (r1, r2, r3, r4, r5). we have derived explicit finite difference method for the all nodes with boundary condition. The all furnace wall has thermal conduction heat transfer between difference nodes and it is according to inside melting metal and outside temperature of atmosphere. The outside of furnace is taken convection cause of cooling water is circulate outside of furnace wall.

This is solved by advanced heat transfer problem of cylindrical induction melting furnace wall. Which is made from silica ramming mass (Basic), in that we have consider initial and boundary condition, material property and some basic assumptions.

In refractory materials for cylindrical furnace wall as basic assumption in the mechanics of science.

- Environmental temperature is homogeneous at 27° C.
- Ignore the influence of heat radiation.
- Ignore the effect of gravity field.
- The surface of induction melting furnace wall is clean.
- Scrap material input inside furnace is considered uniform for our analysis.
- The initial temperature of this furnace is 27 ° C.

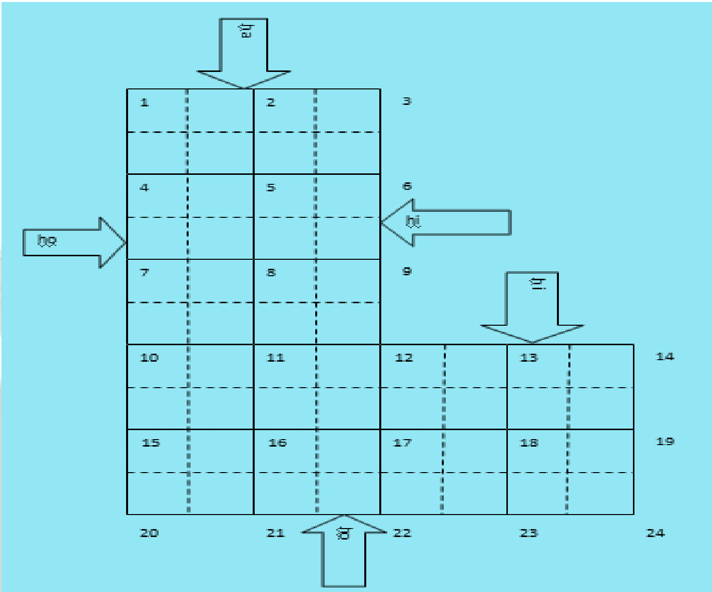

Fig.1 Nodal network for finite difference method

NODE:-1

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

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

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];

NODE:-2

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

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

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]/ ln(r_2/r_3)+k*x*(T[5][i]-T[2][i])/y))*((2*t)/(r*c*x*y)))+T[2][i];

NODE:-3

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

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

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];

NODE:-4

$h_o \Delta y\ (T_\infty - T_4^i) + k\frac{\Delta x}{2}\frac{T_1^i - T_4^i}{\Delta y} + k\frac{\Delta x}{2}\frac{T_7^i - T_4^i}{\Delta y} + \pi k \Delta y \frac{T_5^i - T_4^i}{\ln\left(\frac{r_1}{r_2}\right)} = \rho \frac{\Delta x}{2} \Delta y\ C\ \frac{(T_4^{i+1} - T_4^i)}{\Delta t}$

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

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];

NODE:-5

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

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

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];

NODE:-6

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

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

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];

NODE:-7

$h_o \Delta y\ (T_\infty - T_7^i) + k\frac{\Delta x}{2}\frac{T_4^i - T_7^i}{\Delta y} + k\frac{\Delta x}{2}\frac{T_{10}^i - T_7^i}{\Delta y} + \pi k \Delta y \frac{T_8^i - T_7^i}{\ln\left(\frac{r_1}{r_2}\right)} = \rho \frac{\Delta x}{2} \Delta y\ C\ \frac{(T_7^{i+1} - T_7^i)}{\Delta t}$

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

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];

NODE:-8

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

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

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];

NODE:-9

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

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

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];

NODE:-10

$h_o\Delta y\,(T_\infty\text{-}T_{10}^{\,i}) + k\frac{\Delta x}{2}\frac{T_7^i - T_{10}^i}{\Delta y} + k\frac{\Delta x}{2}\frac{T_{15}^i - T_{10}^i}{\Delta y} + \pi k\Delta y\frac{T_{11}^i - T_{10}^i}{\ln\left(\frac{r_1}{r_2}\right)} = \rho\,\frac{\Delta x}{2}\Delta y\;C\;\frac{(T_{10}^{i+1} - T_{10}^i)}{\Delta t}$

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

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];

NODE:-11

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

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

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];

NODE:-12

$k\frac{\Delta x}{2}\frac{T_9^i - T_{12}^i}{\Delta y} + k\Delta x\frac{T_{17}^i - T_{12}^i}{\Delta y} + h_i\frac{\Delta x}{2}(T_h\text{-}T_{12}^{\,i}) + h_i\frac{\Delta y}{2}(T_h\text{-}T_{12}^{\,i}) + \pi k\Delta y\frac{T_{11}^i - T_{12}^i}{\ln\left(\frac{r_2}{r_3}\right)} + \pi k\Delta y\frac{T_{13}^i - T_{12}^i}{\ln\left(\frac{r_3}{r_4}\right)} = \rho\,\frac{3\Delta x\Delta y}{4}\;C\;\frac{(T_{12}^{i+1} - T_{12}^i)}{\Delta t}$

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

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];

NODE:-13

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

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

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];

NODE:-14

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

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

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];

NODE: -15

$h_o \Delta y\ (T_\infty - T_{15}^i) + k\frac{\Delta x}{2}\frac{T_{10}^i - T_{15}^i}{\Delta y} + k\frac{\Delta x}{2}\frac{T_{20}^i - T_{15}^i}{\Delta y} + \pi k \Delta y \frac{T_{16}^i - T_{15}^i}{\ln\left(\frac{r_1}{r_2}\right)} + \rho\ \frac{\Delta x}{2}\ \Delta y\ C\ \frac{(T_{15}^{i+1} - T_{15}^i)}{\Delta t}$

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

T [15][i+1] = (((h o*y*(Ta– T[15][i])) + (π*k*y*(T[16][i]-T[15][i])/ln(r_1/r2)) + (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];

NODE:-16

$k\Delta x \frac{T_{11}^i - T_{16}^i}{\Delta y} + k\Delta x \frac{T_{21}^i - T_{16}^i}{\Delta y} + \pi k\ \Delta y \frac{T_{15}^i - T_{16}^i}{\ln\left(\frac{r_1}{r_2}\right)} + \pi k \Delta y \frac{T_{17}^i - T_{16}^i}{\ln\left(\frac{r_2}{r_3}\right)} = \rho \Delta x\ \Delta y\ C\ \frac{(T_{16}^{i+1} - T_{16}^i)}{\Delta t}$

$T_{16}^{i+1} = \left((\pi k\ \Delta y \frac{T_{15}^i - T_{16}^i}{\ln\left(\frac{r_1}{r_2}\right)} + \pi k \Delta y \frac{T_{17}^i - T_{16}^i}{\ln\left(\frac{r_2}{r_3}\right)} + k\Delta x \frac{T_{11}^i - T_{16}^i}{\Delta y} + k\Delta x \frac{T_{21}^i - T_{16}^i}{\Delta y}\right)\frac{\Delta t}{\rho C \Delta x \Delta y}\right) + T_{16}^i$

T [16][i+1] = ((π*k*y*(T[15][i]-T[16][i])/ln(r_1/r2)) + (π*k*y*(T[17][i]-T[16][i])/ln(r_2/r3)) + (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];

NODE: -17

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

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

T [17][i+1] = ((π*k*y*(T[16][i]-T[17][i])/ln(r_2/r3)) +(π*k*y*(T[18][i]-T[17][i])/ln(r_3/r4)) + (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];

NODE: -18

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

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

T [18][i+1] = ((π*k*y*(T[17][i]-T[18][i])/ln(r_3/r4)) + (π*k*y*(T[19][i]-T[18][i])/ln(r_4/r5)) + (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];

NODE:-19

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

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

T [19][i+1] = ((hi*y*(Th– T[19][i])) + (π*k*y*(T[18][i]-T[19][i])/ln(r_4/r5)) + (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];

NODE:-20

$h_o\frac{\Delta x}{2}(T_\infty - T_{20}^i) + ((h_o\frac{\Delta y}{2}(T_\infty - T_{20}^i) + \pi k \Delta y \frac{T_{21}^i - T_{20}^i}{\ln\left(\frac{r_1}{r_2}\right)} + k\frac{\Delta x}{2}\frac{T_{15}^i - T_{20}^i}{\Delta y} = \rho\ \frac{\Delta x}{2}\ \frac{\Delta y}{2}\ C\ \frac{(T_{20}^{i+1} - T_{20}^i)}{\Delta t}$

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

T [20][i+1] = (((0.5*h o*x*(Ta– T[20][i])) + (0.5*ho*y*(Ta– T[20][i])) +(π*k*y*(T[21][i]-T[20][i])/ln(r_1/r2)) +(0.5*x*k*(T[15][i]-T[20][i]/y))*((4*t)/(r*c*x*y)))+T[20][i];

NODE:-21

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

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

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];

NODE:-22

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

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

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];

NODE: -23 +

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

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

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];

NODE: -24

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

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

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];

IV. EXPERIMENTAL VALIDATION

We have seen that during experimental of cylindrical type induction furnace for melting basic ferrous alloy with wall of furnace made by silica ramming mass (Basic).it is initially temperature starting from 15ºC-20ºC and increase within 1-minute 30ºC - 35ºC. This temperature is change up to 25 minute of material melting. Then after induction furnace is increase temperature with 40 ºC - 45ºC up to 46 minute of melting process. Here is increase at that time stress also increases.

Fig.2 Cylindrical Induction Furnace during melting process

In 46 minutes, metal is fully melted in furnace then there is pouring process is start it depends on shape, size and length of mould. The minimum time is taken 5 seconds and maximum is 5 minutes.

Fig.3 After pouring process

After pouring process the furnace is decrease temperature 30 ºC - 35ºC with in every minute. Here, temperature is decreases then stress also decreases. In that next melting cycle is start.

V. RESULT OUTPUT

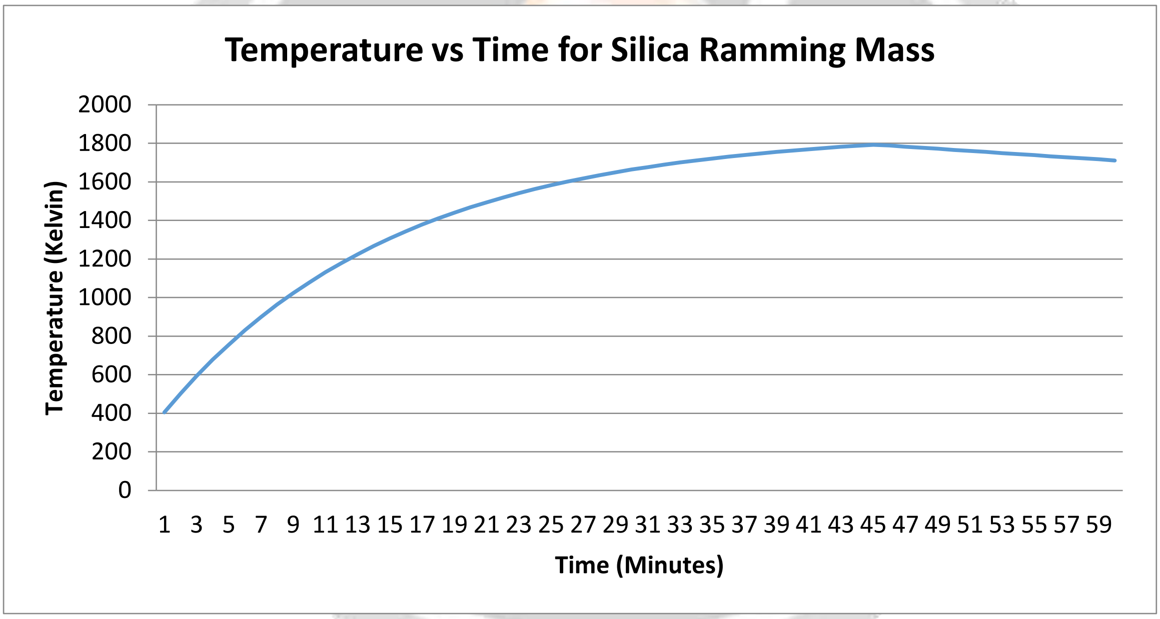

Fig. 4 Temperature v/s Time for Silica Ramming Mass

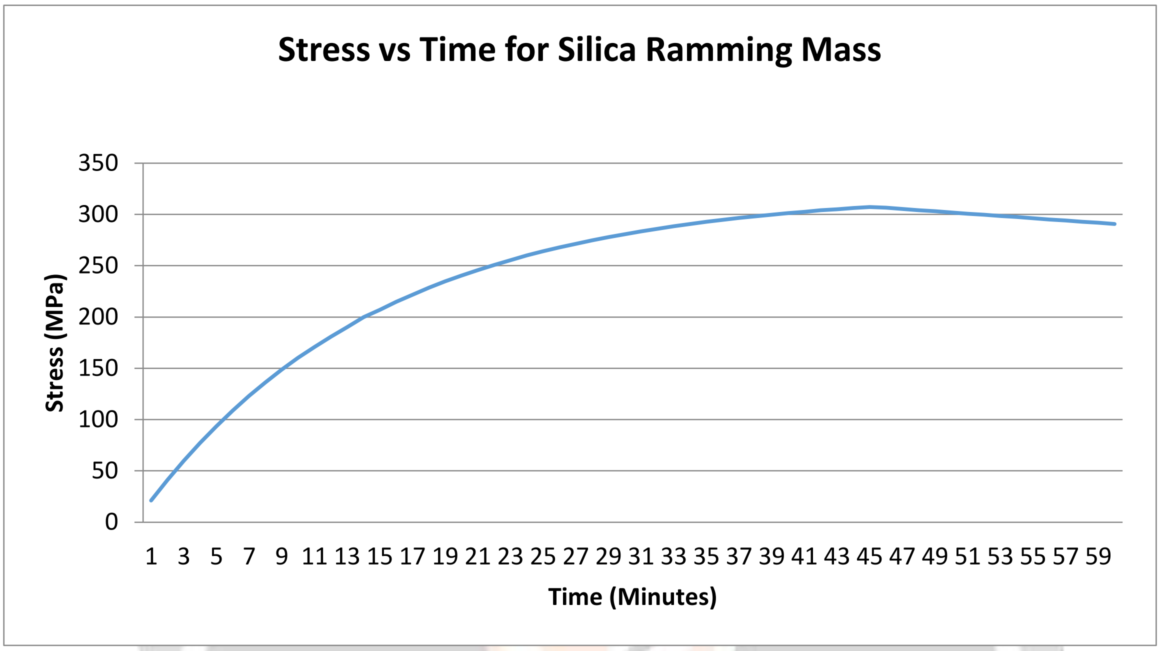

Fig. 5 Stress v/s Time for Silica Ramming Mass

VI. CONCLUSION

Induction type cylindrical and spherical furnace are highly use for melting of different kinds of material in that problem comes from the zirconia of losing its properties and failure occurs with life cycle 200 hours of life time. It will disturb production schedule in industries. So, it is required finding of life cycle of zirconia material wall furnace by explicit finite different analysis method. The condition is plotted on S-log N-curves are plotted for life span prediction. We found life span of different materials like, zirconia, silica, fire-bricks, high alumina by this mathematical program and exactly predicts and failure of induction furnace refractory wall. The accuracy of the fatigue life prediction for the induction type cylindrical and spherical melting furnaces refractory wall depend upon temperature and thermal stress calculated at critical point by this method.

REFERENCES

[1] H, Kohne R, Nitsch J, Sprengel U, Solar thermal power plants for solar countries—technology, economics and market potential, Applied Energy 52(2–3), 1995; 165–83.
[2] Mancini TR, Kolb GJ, Chavez JM, Solar thermal power today and tomorrow, Mech. Engg., 116(8), 1994, 74–9.
[3] Ravi Kumar K, Reddy KS, Thermal analysis of solar parabolic trough with porous disc receiver. Applied Energy 86(9), 2009, 1804–12.
[4] Vanita Thakkar, Status of Parabolic Dish Solar Concentrators, International Journal of Enhanced Research in Science Technology & Engineering Vol. 2 Issue 6, June-2013, pp – 42-50
[5] S. A. Kalogirou, Solar thermal collectors and applications. Prgress in Energy and Combustion Science, 2004. 30: p. 231-295.
[6] Australian Energy Resource Asssessment, Solar Energy.
[7] A. Sazena and S. Ghanshyam, Performance studies of a multipurpose solar Energy System for Remote areas. MIT International Journal of Mchanical Engineering, 2013. 3(1): p. 21-33.
[8] S. A. Kalogirou, Solar thermal collectors and applications. Prgress in Energy and Combustion Science, 2004. 30: p. 231-295.
[9] B.SriHariPriya, R.SantoshiKumari, M.TukaramBai, V.Sridevi, Review on Water Desalination using Renewable Solar Energy. IJIRST –International Journal for Innovative Research in Science & Technology| Volume 2 | Issue 07 | December 2015.
[10] Philippe SCHILD,European Commission on Concentrated Solar Thermal Energy, Office CDMA 5-141,B-1049 Brussels.
[11] M. Ouannene, B. Chaouachi, S.Gabsi, design and realisation of a parabolic solar cooker. National School of Engineers of Gabes (E.N.I.G) - Omar IbnElKhattab Street -6029 Gabes-Tunisia.
[12] Nirajkumar Mehta, (May 2012), Review on Computational Investigation on Different Kinds of Furnaces, International Conference on Emerging Technologies and Applications in Engineering, Technology and Sciences, Volume 3, pp 1 – 7.
[13] S. O. Jimoh (2013), analysis of the characteristics of the blast furnaces peripherical zone, international journal of science and technology research
[14] N C Mehta, Vipul B Gondaliya, Jayesh V Gundaniya, (February 2013), Applications of Different Numerical Methods in Heat Transfer - A Review, International Journal of Emerging Technology and Advanced Engineering, Volume 3, Issue 2, pp 363 – 368.
[15] Camilolezcano (2013), Numerical calculation of the recirculation factor in flameless furnaces, ISSN 0012-7353, pp 144-151.
[16] N C Mehta, Viral V Shiyani, Jemish R Nasit, (May 2013), Metal Forming Analysis, International Journal of Emerging Technology and Advanced Engineering, Volume 3, Issue 5, pp 190 - 196.
[17] Vipul Gondaliya, Mehul Pujara, Nirajkumar Mehta, (August 2013), Transient Heat Transfer Analysis of Induction Furnace by Using Finite Element Analysis, International Journal of Applied Research, Volume 3, Issue 8, pp 231 – 234.
[18] N C Mehta, Vasim G Machhar, Ravi K Popat, (October 2013), Thermal Fatigue Analysis of Induction Furnace Wall for Alumina ramming mass, International Journal of Science and Engineering Applications, Volume 2, Issue 10, pp 186 – 190, DOI: 10.7753/IJSEA0210.1002.
[19] Gaurav Kumar Thakur (2013), Analysis of fuel injection in blast furnaces with the help of CFD software approach, international journal of scientific and research publication, volume 3, issue 3, ISSN 2250-3153, page no-1-7.
[20] N C Mehta, Akash D Raiyani, Vikas R Gondalia, (February 2013), Thermal Fatigue Analysis of Induction Melting Furnace Wall for Silica ramming mass, International Journal of Emerging Technology and Advanced Engineering, Volume 3, Issue 2, pp 357 – 362.
[21] Vimal R Nakum, Kevin M Vyas, Niraj C Mehta, (April 2013), Research on Induction Heating - A Review, International Journal of Science and Engineering Applications, Volume 2, Issue 6, pp 141 – 144, DOI: 10.7753/IJSEA0206.1005.
[22] Andrey V Gil (2015), Research of integral parameters for furnaces of a circulating fluidized bed, EDP publication science, EPJ web of conference 82,01044, page no-01044-p.1-01044-p.5.

[23] Nirajkumar C Mehta, Dipesh D Shukla, Ravi K Popat, (December 2014), Optimization of Wall Thickness for Minimum Heat Loss for Induction Furnace by FEA, Indian Foundry Journal, Volume 60, No. 12, pp 19-25.

[24] Nirajkumar C Mehta, Dr. Dipesh D Shukla, Vishvash B Rajyaguru, (April 2015), Numerical Analysis of Furnace: Review, National Conference on Recent Research and Development in Core Disciplines of Engineering, Vadodara, Volume: 2, pp 1 -7.

[25] Nirajkumar C Mehta, Dr. Dipesh D Shukla, Vishvash B Rajyaguru, (April 2015), Thermal Fatigue Analysis of Induction Furnace Wall for Zirconia, National Conference on Recent Research and Development in Core Disciplines of Engineering, Vadodara, Volume: 2, pp 1 – 6.

[26] Nirajkumar C Mehta, Dr. Dipesh D Shukla, Pragnesh D Kandoliya, (April 2015), Comparison of Finite Difference Method and Finite Element Method for 2 D Transient Heat Transfer Problem, National Conference on Recent Research and Development in Core Disciplines of Engineering, Vadodara, Volume: 2, pp 1 – 10.

[27] Saheedlekangbad Mosi (2015), Effect of steel plants with three-phase induction furnaces on power distribution quality of the existing 33kv network in Nigeria, advance in science and technology research journal, volume 9, no.27, pages 1-10.

[28] Nirajkumar C Mehta, Dr. Dipesh D Shukla, (June 2015), Thermal Fatigue Analysis of Induction Furnace Wall for Magnesia Ramming Mass, ASME 2015 Applied Mechanics and Materials Conference, At Seattle, Washington, United States of America, Volume: 12, pp 1 – 6.

[29] Nirajkumar C Mehta, Dr. Dipesh D Shukla, Pragnesh D Kandoliya, (December 2016), Advanced Mathematical Modeling of Heat Transfer in Induction Furnace Wall of Zirconia, International Journal of Engineering Research and Technology, Volume 5, Issue 10, pp 176 – 181, DOI: 10.17577/IJERTV5IS120128

[30] Nirajkumar C Mehta, Dr. Dipesh D Shukla, Pragnesh D Kandoliya, (December 2016), Advanced Heat Transfer Analysis of Alumina Based Refractory Wall of Induction Furnace, National Conference on Emerging Trends in Engineering, Volume 1, pp 1 – 6.

[31] Piotr Bulinski (2016), coupled numerical model of metal melting in an induction furnace: sensitivity analysis and validation of model, Silesian university of technology, institute of thermal technology and Silesian university of technology, department of industrial informatics, ISSN 0033-2097

[32] Mirko Filipponi (2016), thermal analysis of an industrial furnace, MDPI Energies, 2016, 9, 833, 1-30.

[33] Prof. Nirajkumar C. Mehta, Dr. Dipesh D. Shukla, (December 2017) Mathematical Modelling for Life Cycle Forecasting of Zirconia Based Furnace Wall, International Journal of Advance Research and Innovative Ideas in Education, IJARIIE, ISSN(O)-2395-4396, Vol-3 Issue-4 2017, pp 796-807.

[34] Nirajkumar C Mehta, Dr. Dipesh D Shukla, Stress analysis of induction furnace wall for magnesia ramming mass, Journal of Metallurgy and Materials Science, Volume: 59, Issue: 2, pp. 85-110, Print ISSN: 0972-4257. Online ISSN: 0974-1267, November 2017.

[35] Nirajkumar C Mehta, Dr. Dipesh D Shukla, Comparison of Life Cycle for Various Refractory Materials of Induction Melting Furnace Wall under Thermal Fatigue Loading Conditions", International Journal of Advance Engineering and Research Development, e-ISSN (O): 2348-4470, p-ISSN (P): 2348-6406, Volume 5, Issue 01, January 2018.

[36] Patil Kaushal, Makwana Arjunsinh, Arab Mohammadazhar, Nirajkumar C Mehta, "Mathematically Advanced Computational Heat Transfer Analysis of Cylindrical and Spherical Induction Furnaces: Review", International Journal of Advance Engineering and Research Development, e-ISSN (O): 2348-4470, p-ISSN (P): 2348-6406, Volume 5, Issue 02, February 2018.

[37] Ronik Varia, Sachin Vasani, Rahul Varma, Dr. Nirajkumar C Mehta, "Review of Solar Heating Furnace Development", International Journal of Advance Engineering and Research Development, e-ISSN (O): 2348-4470, p-ISSN (P): 2348-6406, Volume 5, Issue 03, March -2018.

[38] Rahul Waghela, Shreyas Parmar, Susmit Vasava, Dr. Nirajkumar C Mehta, "Review of Refractory Materials for Innovative Investigation and Testing", International Journal of Advance Engineering and Research