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Comparison of Life Cycle for Various Refractory Materials of Induction Melting Furnace Wall under Thermal Fatigue Loading Conditions

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Abstract - *Furnaces are most important as it is constantly used for melting of materials. Induction furnaces are more worthwhile as no fuel is required. It is a main issue to go looking out life cycle of Induction Melting Furnace Wall under load variant. The induction melting furnace wall is made-up of Silica Ramming Mass, Alumina Ramming Mass, Magnesia Ramming Mass and Zirconia which are forms of refractory materials. The failure occurs considering that of cyclic thermal stresses as a result of heating and cooling cycles. Temperature distribution and thermal stress distribution fields of the induction melting furnace refractory wall had been calculated by way of utilising explicit finite change evaluation centred on the bodily description of its failure under low cycle thermal fatigue stipulations. The life span of the refractory wall is required to be found out by the use of primary thermal stresses created inside the refractory wall of induction melting furnace wall from modified S – log N Curves.*

Key words: *Advanced mathematical modeling, Temperature distribution, Stress distribution, Explicit finite difference method, Zirconia, Silica Ramming Mass, Alumina Ramming Mass, Magnesia Ramming Mass*

I. INTRODUCTION

Furnace is a device used to identify a closed location proper here heat is utilized to a physique in order to elevate its temperature. The provider of heat would also be via gas or electricity. Most traditionally, metals and alloys and frequently non-metals are heated in furnaces. The intent of heating defines the temperature of heating and heating expense. Increase in temperature softens the metals. They develop to be amenable to deformation. This softening happens with or and not utilizing an alternate within the metal composition. Heating to relevant temperatures of the steel softens it via relieving the inner stresses. Then again, metals heated to temperatures above the important temperatures results in alterations in crystal buildings and recrystallization like annealing. Extra some metals and alloys are melted, ceramic products vitrified, coals coked, metals like zinc are vaporized and a lot of specific conducts are carried out in Furnaces.

Induction furnaces are greatly used within the iron industry for the casting of the exceptional grades of forged iron products. Refractory wall of induction melting furnace is a key factor which is used as insulation layer. It is product of ramming mass like silica, alumina, magnesia and many others. The refractory wall is directly influenced via the thermal biking of the high temperature molten iron within the furnace. Thermal fatigue failure is natural to occur for it on the grounds that of the larger section transformation thermal stresses and it has a shorter life. This may intent severe creation accidents. As a result, the service life as main issue of the refractory wall has at all times been a center of consideration of attention in the application of this to the industry.

Here, Advanced Numerical Methodology is implemented to find out temperature and thermal stress variation with respect to time.

II. DEVELOPMENT OF ADVANCED MATHEMATICAL MODEL

We have now divided Induction Furnace Wall into a Nodal network as proven in Figure 1. It is divided into 24 nodes. We have now derived Finite Change Equations for all nodes as per the boundary stipulations utilized to it. The furnace wall is having thermal conduction heat change between nodes. It is having atmospheric heat convection ha utilized from prime aspect of the furnace wall which is open to surroundings. It is having heat convection from molten metal from within 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, the following initial and boundary conditions, material properties and basic assumptions are made:

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Refractory Materials for induction furnace wall meets the basic assumptions in the science of mechanics.

- Environmental Temperature is similar at 27° C.
- Ignore the effect of heat radiation.
- Ignore the consequence of gravity field.
- The surface of induction melting furnace wall is clean.
- The initial temperature of the induction melting furnace is set 27° C and it is covenant with the ambient temperature during solving the problem.
- Heat convections are considered continuous for this investigation.
- Scarp material input inside furnace is considered unchanging for our investigation.

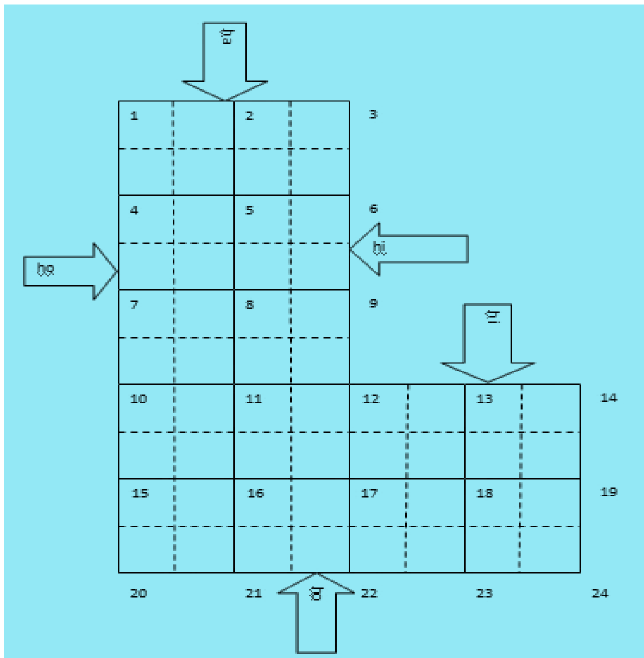

Figure 1 Nodal network for finite difference method

Node 1:

$$ha\frac{\Delta x}{2}(T_\infty - T_1^i) + ho\frac{\Delta y}{2}(T_\infty - T_1^i) + k\frac{\Delta y}{2}\frac{T_2^i - T_1^i}{\Delta x} + k\frac{\Delta x}{2}\frac{T_4^i - T_1^i}{\Delta y} = \rho\frac{\Delta x}{2}\frac{\Delta y}{2}C\frac{T_1^{i+1} - T_1^i}{\Delta t}$$

$$T_1^{i+1} = ((ha\frac{\Delta x}{2}(T_\infty - T_1^i) + ho\frac{\Delta y}{2}(T_\infty - T_1^i) + k\frac{\Delta y}{2}\frac{T_2^i - T_1^i}{\Delta x} + k\frac{\Delta x}{2}\frac{T_4^i - T_1^i}{\Delta y})\frac{4\Delta t}{\rho C\Delta x\Delta y}) + T_1^i$$

T[1][i+1] = (((0.5*ha*x*(To-T[1][i])) +(ho*y*(Ta-T[1][i])/2)+(0.5*k*y*(T[2][i]-T[1][i])/x)+(0.5*k*x*(T[4][i]-T[1][i])/y))*((4*t)/(r*c*x*y))) +T[1][i];

Node 2:

$$ha\Delta x(T_\infty - T_2^i) + k\frac{\Delta y}{2}\frac{T_1^i - T_2^i}{\Delta x} + k\frac{\Delta y}{2}\frac{T_3^i - T_2^i}{\Delta x} + k\Delta x\frac{T_5^i - T_2^i}{\Delta y} = \rho\Delta x\frac{\Delta y}{2}C\frac{T_2^{i+1} - T_2^i}{\Delta t}$$

$$T_2^{i+1} = ((ha\Delta x(T_\infty - T_2^i) + k\frac{\Delta y}{2}\frac{T_1^i - T_2^i}{\Delta x} + k\frac{\Delta y}{2}\frac{T_3^i - T_2^i}{\Delta x} + k\Delta x\frac{T_5^i - T_2^i}{\Delta y})\frac{2\Delta t}{\rho C\Delta x\Delta y}) + T_2^i$$

T[2][i+1] = (((ha*x*(To-T[2][i]))+(0.5*k*y*(T[1][i]-T[2][i])/x)+(0.5*k*y*(T[3][i]-T[2][i])/x) +(0.5*k*x*(T[5][i]-T[2][i])/y))*((2*t)/(r*c*x*y))) +T[2][i];

Node 3:

$$ha\frac{\Delta x}{2}(T_\infty - T_3^i) + hi\frac{\Delta y}{2}(T_h - T_3^i) + k\frac{\Delta y}{2}\frac{T_2^i - T_3^i}{\Delta x} + k\frac{\Delta x}{2}\frac{T_6^i - T_3^i}{\Delta y} = \rho\frac{\Delta x}{2}\frac{\Delta y}{2}C\frac{T_3^{i+1} - T_3^i}{\Delta t}$$

$$T_3^{i+1} = ((ha\frac{\Delta x}{2}(T_\infty - T_3^i) + hi\frac{\Delta y}{2}(T_h - T_3^i) + k\frac{\Delta y}{2}\frac{T_2^i - T_3^i}{\Delta x} + k\frac{\Delta x}{2}\frac{T_6^i - T_3^i}{\Delta y})\frac{4\Delta t}{\rho C\Delta x\Delta y}) + T_3^i$$

T[3][i+1] = (((ha*x*(To-T[3][i])*0.5) +(hi*y*(Th-T[3][i])*0.5) +(0.5*k*y*(T[2][i]-T[3][i])/x)+(0.5*k*x*(T[6][i]-T[3][i])/y)) *((4*t)/(r*c*x*y))) +T[3][i];

Node 4:

$$ho\Delta y(T_\infty - T_4^i) + \text{k}\Delta y\frac{T_5^i - T_4^i}{\Delta x} + \text{k}\frac{\Delta x}{2}\frac{T_1^i - T_4^i}{\Delta y} + \text{k}\frac{\Delta x}{2}\frac{T_7^i - T_4^i}{\Delta y} = \rho\frac{\Delta x}{2}\Delta y\text{C}\frac{T_4^{i+4} - T_4^i}{\Delta t}$$

$$T_4^{i+4} = ((ho\Delta y(T_\infty - T_4^i) + \text{k}\Delta y\frac{T_5^i - T_4^i}{\Delta x} + \text{k}\frac{\Delta x}{2}\frac{T_1^i - T_4^i}{\Delta y} + \text{k}\frac{\Delta x}{2}\frac{T_7^i - T_4^i}{\Delta y})\frac{2\Delta t}{\rho\text{C}\Delta x\Delta y}) + T_4^i$$

T[4][i+1] = (((ho*y*(Ta-T[4][i])) +(k*y*(T[5][i]-T[4][i])/x)+(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:

$$\text{k}\Delta y\frac{T_4^i - T_5^i}{\Delta x} + \text{k}\Delta y\frac{T_6^i - T_5^i}{\Delta x} + \text{k}\Delta x\frac{T_2^i - T_5^i}{\Delta y} + \text{k}\Delta x\frac{T_8^i - T_5^i}{\Delta y} = \rho\Delta x\Delta y\text{C}\frac{T_5^{i+1} - T_5^i}{\Delta t}$$

$$T_5^{i+1} = ((\text{k}\Delta y\frac{T_4^i - T_5^i}{\Delta x} + \text{k}\Delta y\frac{T_6^i - T_5^i}{\Delta x} + \text{k}\Delta x\frac{T_2^i - T_5^i}{\Delta y} + \text{k}\Delta x\frac{T_8^i - T_5^i}{\Delta y})\frac{\Delta t}{\rho\text{C}\Delta x\Delta y}) + T_5^i$$

T[5][i+1] = (((k*y*(T[4][i]-T[5][i])/x)+(k*y*(T[6][i]-T[5][i])/x) + (k*x*(T[8][i]-T[5][i])/y)) *((t)/(r*c*x*y))) +T[5][i];

Node 6:

$$hi\Delta y(T_h - T_6^i) + \text{k}\Delta y\frac{T_2^i - T_6^i}{\Delta x} + \text{k}\frac{\Delta x}{2}\frac{T_3^i - T_6^i}{\Delta y} + \text{k}\frac{\Delta x}{2}\frac{T_9^i - T_6^i}{\Delta y} = \rho\frac{\Delta x}{2}\Delta y\text{C}\frac{T_6^{i+1} - T_6^i}{\Delta t}$$

$$T_6^{i+1} = ((hi\Delta y(T_h - T_6^i) + \text{k}\Delta y\frac{T_2^i - T_6^i}{\Delta x} + \text{k}\frac{\Delta x}{2}\frac{T_3^i - T_6^i}{\Delta y} + \text{k}\frac{\Delta x}{2}\frac{T_9^i - T_6^i}{\Delta y})\frac{2\Delta t}{\rho\text{C}\Delta x\Delta y}) + T_6^i$$

T[6][i+1] = (((hi*y*(Th-T[6][i])) + (k*y*(T[2][i]-T[6][i])/x)+(0.5*k*x*(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:

$$ho\Delta y(T_\infty - T_7^i) + \text{k}\Delta y\frac{T_8^i - T_7^i}{\Delta x} + \text{k}\frac{\Delta x}{2}\frac{T_4^i - T_7^i}{\Delta y} + \text{k}\frac{\Delta x}{2}\frac{T_{10}^i - T_7^i}{\Delta y} = \rho\frac{\Delta x}{2}\Delta y\text{C}\frac{T_7^{i+7} - T_7^i}{\Delta t}$$

$$T_7^{i+7} = ((ho\Delta y(T_\infty - T_7^i) + \text{k}\Delta y\frac{T_8^i - T_7^i}{\Delta x} + \text{k}\frac{\Delta x}{2}\frac{T_4^i - T_7^i}{\Delta y} + \text{k}\frac{\Delta x}{2}\frac{T_{10}^i - T_7^i}{\Delta y})\frac{2\Delta t}{\rho\text{C}\Delta x\Delta y}) + T_7^i$$

T[7][i+1] = (((ho*y*(Ta-T[7][i])) + (k*y*(T[8][i]-T[7][i])/x)+(0.5*k*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:

$$\text{k}\Delta y\frac{T_7^i - T_8^i}{\Delta x} + \text{k}\Delta y\frac{T_9^i - T_8^i}{\Delta x} + \text{k}\Delta x\frac{T_5^i - T_8^i}{\Delta y} + \text{k}\Delta x\frac{T_{11}^i - T_8^i}{\Delta y} = \rho\Delta x\Delta y\text{C}\frac{T_8^{i+1} - T_8^i}{\Delta t}$$

$$T_8^{i+1} = ((\text{k}\Delta y\frac{T_7^i - T_8^i}{\Delta x} + \text{k}\Delta y\frac{T_9^i - T_8^i}{\Delta x} + \text{k}\Delta x\frac{T_5^i - T_8^i}{\Delta y} + \text{k}\Delta x\frac{T_{11}^i - T_8^i}{\Delta y})\frac{\Delta t}{\rho\text{C}\Delta x\Delta y}) + T_8^i$$

T[8][i+1] = (((k*y*(T[7][i]-T[8][i])/x)+(k*y*(T[9][i]-T[8][i])/x) +(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:

$$hi\Delta y(T_h - T_9^i) + \text{k}\Delta y\frac{T_8^i - T_9^i}{\Delta x} + \text{k}\frac{\Delta x}{2}\frac{T_6^i - T_9^i}{\Delta y} + \text{k}\frac{\Delta x}{2}\frac{T_{12}^i - T_9^i}{\Delta y} = \rho\frac{\Delta x}{2}\Delta y\text{C}\frac{T_9^{i+1} - T_9^i}{\Delta t}$$

$$T_9^{i+1} = ((hi\Delta y(T_h - T_9^i) + \text{k}\Delta y\frac{T_8^i - T_9^i}{\Delta x} + \text{k}\frac{\Delta x}{2}\frac{T_6^i - T_9^i}{\Delta y} + \text{k}\frac{\Delta x}{2}\frac{T_{12}^i - T_9^i}{\Delta y})\frac{2\Delta t}{\rho\text{C}\Delta x\Delta y}) + T_9^i$$

T[9][i+1] = (((hi*y*(Th-T[9][i]))+(k*y*(T[8][i]-T[9][i])/x)+ (0.5*k*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:

$$ho\Delta y(T_\infty - T_{10}^i) + \text{k}\Delta y\frac{T_{11}^i - T_{10}^i}{\Delta x} + \text{k}\frac{\Delta x}{2}\frac{T_7^i - T_{10}^i}{\Delta y} + \text{k}\frac{\Delta x}{2}\frac{T_{15}^i - T_{10}^i}{\Delta y} = \rho\frac{\Delta x}{2}\Delta y\text{C}\frac{T_{10}^{i+10} - T_{10}^i}{\Delta t}$$

$$T_{10}^{i+10} = ((ho\Delta y(T_\infty - T_{10}^i) + \text{k}\Delta y\frac{T_{11}^i - T_{10}^i}{\Delta x} + \text{k}\frac{\Delta x}{2}\frac{T_7^i - T_{10}^i}{\Delta y} + \text{k}\frac{\Delta x}{2}\frac{T_{15}^i - T_{10}^i}{\Delta y})\frac{2\Delta t}{\rho\text{C}\Delta x\Delta y}) + T_{10}^i$$

T[10][i+1] = (((ho*y*(Ta-T[10][i]))+(k*y*(T[11][i]-T[10][i])/x)+ (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:

$$\text{k}\Delta y\frac{T_{10}^i - T_{11}^i}{\Delta x} + \text{k}\Delta y\frac{T_{12}^i - T_{11}^i}{\Delta x} + \text{k}\Delta x\frac{T_8^i - T_{11}^i}{\Delta y} + \text{k}\Delta x\frac{T_{16}^i - T_{11}^i}{\Delta y} = \rho\Delta x\Delta y\text{C}\frac{T_{11}^{i+1} - T_{11}^i}{\Delta t}$$

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$$T_{11}^{i+1} = ((\, k\Delta y\frac{T_{10}^{i}-T_{11}^{i}}{\Delta x} + k\Delta y\frac{T_{12}^{i}-T_{11}^{i}}{\Delta x} + k\Delta x\frac{T_{8}^{i}-T_{11}^{i}}{\Delta y} + k\Delta x\frac{T_{16}^{i}-T_{11}^{i}}{\Delta y}\,)\ \frac{\Delta t}{\rho C\Delta x\Delta y}\,) +\ T_{11}^{i}$$

T[11][i+1] = (((k*y*(T[10][i]-T[11][i])/x)+ (k*y*(T[12][i]-T[11][i])/x)+ (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:

$$hi\,\frac{\Delta x}{2}(T_h - T_{12}^{i}) + hi\,\frac{\Delta y}{2}(T_h - T_{12}^{i}) + k\Delta y\frac{T_{11}^{i}-T_{12}^{i}}{\Delta x} + k\frac{\Delta y}{2}\frac{T_{13}^{i}-T_{12}^{i}}{\Delta x} + k\frac{\Delta x}{2}\frac{T_{9}^{i}-T_{12}^{i}}{\Delta y} + k\Delta x\frac{T_{17}^{i}-T_{12}^{i}}{\Delta y} = \rho\,\frac{3\Delta x\Delta y}{4}\,C\,\frac{T_{12}^{i+1}-T_{12}^{i}}{\Delta t}$$

$$T_{12}^{i+1} = ((\, hi\,\frac{\Delta x}{2}(T_h - T_{12}^{i}) +\ hi\,\frac{\Delta y}{2}(T_h - T_{12}^{i}) + k\Delta y\frac{T_{11}^{i}-T_{12}^{i}}{\Delta x} +\ k\frac{\Delta y}{2}\frac{T_{13}^{i}-T_{12}^{i}}{\Delta x}\ +\ k\frac{\Delta x}{2}\frac{T_{9}^{i}-T_{12}^{i}}{\Delta y}\ +\ k\Delta x\frac{T_{17}^{i}-T_{12}^{i}}{\Delta y}\,)\ \frac{4\Delta t}{3\rho C\Delta x\Delta y}\,) + T_{12}^{i}$$

T[12][i+1] = (((0.5*hi*x*(Th-T[12][i]))+(0.5*hi*y*(Th-T[12][i])) +(k*y*(T[11][i]-T[12][i])/x)+ (0.5*k*y*(T[13][i]-T[12][i])/x) + (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:

$$hi\Delta x(T_h - T_{13}^{i}) + k\frac{\Delta y}{2}\frac{T_{12}^{i}-T_{13}^{i}}{\Delta x} + k\frac{\Delta y}{2}\frac{T_{14}^{i}-T_{13}^{i}}{\Delta x} + k\Delta x\frac{T_{18}^{i}-T_{13}^{i}}{\Delta y} = \rho\Delta x\,\frac{\Delta y}{2}\,C\,\frac{T_{13}^{i+1}-T_{13}^{i}}{\Delta t}$$

$$T_{13}^{i+1} = ((\, hi\Delta x(T_h - T_{13}^{i}) + k\frac{\Delta y}{2}\frac{T_{12}^{i}-T_{13}^{i}}{\Delta x} + k\frac{\Delta y}{2}\frac{T_{14}^{i}-T_{13}^{i}}{\Delta x} + k\Delta x\frac{T_{18}^{i}-T_{13}^{i}}{\Delta y})\ \frac{2\Delta t}{\rho C\Delta x\Delta y}\,) + T_{13}^{i}$$

T[13][i+1] = (((hi*x*(Th-T[13][i]))+(0.5*k*y*(T[12][i]-T[13][i])/x)+ (0.5*k*y*(T[14][i]-T[13][i])/x)+ (k*x*(T[18][i]-T[13][i])/y)) *((2*t)/(r*c*x*y))) +T[13][i];

Node 14:

$$hi\,\frac{\Delta x}{2}(T_h - T_{14}^{i}) +\ hi\,\frac{\Delta y}{2}(T_h - T_{14}^{i}) + k\frac{\Delta y}{2}\frac{T_{13}^{i}-T_{14}^{i}}{\Delta x} + k\frac{\Delta x}{2}\frac{T_{19}^{i}-T_{14}^{i}}{\Delta y} = \rho\,\frac{\Delta x}{2}\frac{\Delta y}{2}\,C\,\frac{T_{14}^{i+1}-T_{14}^{i}}{\Delta t}$$

$$T_{14}^{i+1} = ((\, hi\,\frac{\Delta x}{2}(T_h - T_{14}^{i}) +\ hi\,\frac{\Delta y}{2}(T_h - T_{14}^{i}) + k\frac{\Delta y}{2}\frac{T_{13}^{i}-T_{14}^{i}}{\Delta x} + k\frac{\Delta x}{2}\frac{T_{19}^{i}-T_{14}^{i}}{\Delta y})\ \frac{4\Delta t}{\rho C\Delta x\Delta y}\,) + T_{14}^{i}$$

T[14][i+1] = (((0.5*hi*x*(Th-T[14][i]))+(0.5*hi*y*(Th-T[14][i])) +(0.5*k*y*(T[13][i]-T[14][i])/x)+ (0.5*k*x*(T[19][i]-T[14][i])/y)) *((4*t)/(r*c*x*y))) +T[14][i];

Node 15:

$$ho\Delta y(T_\infty - T_{15}^{i}) + k\Delta y\frac{T_{16}^{i}-T_{15}^{i}}{\Delta x} + k\frac{\Delta x}{2}\frac{T_{10}^{i}-T_{15}^{i}}{\Delta y} + k\frac{\Delta x}{2}\frac{T_{20}^{i}-T_{15}^{i}}{\Delta y} = \rho\,\frac{\Delta x}{2}\,\Delta y C\,\frac{T_{15}^{i+15}-T_{15}^{i}}{\Delta t}$$

$$T_{15}^{i+15} = ((\, ho\Delta y(T_\infty - T_{15}^{i}) + k\Delta y\frac{T_{16}^{i}-T_{15}^{i}}{\Delta x} + k\frac{\Delta x}{2}\frac{T_{10}^{i}-T_{15}^{i}}{\Delta y} + k\frac{\Delta x}{2}\frac{T_{20}^{i}-T_{15}^{i}}{\Delta y})\ \frac{2\Delta t}{\rho C\Delta x\Delta y}\,) + T_{15}^{i}$$

T[15][i+1] = (((ho*y*(Ta-T[15][i]))+(k*y*(T[16][i]-T[15][i])/x)+ (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:

$$k\Delta y\frac{T_{15}^{i}-T_{16}^{i}}{\Delta x} + k\Delta y\frac{T_{17}^{i}-T_{16}^{i}}{\Delta x} + k\Delta x\frac{T_{11}^{i}-T_{16}^{i}}{\Delta y} + k\Delta x\frac{T_{21}^{i}-T_{16}^{i}}{\Delta y} = \rho\Delta x\Delta y C\,\frac{T_{16}^{i+1}-T_{16}^{i}}{\Delta t}$$

$$T_{16}^{i+1} = ((\, k\Delta y\frac{T_{15}^{i}-T_{16}^{i}}{\Delta x} + k\Delta y\frac{T_{17}^{i}-T_{16}^{i}}{\Delta x} + k\Delta x\frac{T_{11}^{i}-T_{16}^{i}}{\Delta y} + k\Delta x\frac{T_{21}^{i}-T_{16}^{i}}{\Delta y})\ \frac{\Delta t}{\rho C\Delta x\Delta y}\,) + T_{16}^{i}$$

T[16][i+1] = (((k*y*(T[15][i]-T[16][i])/x)+ (k*y*(T[17][i]-T[16][i])/x)+(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:

$$k\Delta y\frac{T_{16}^{i}-T_{17}^{i}}{\Delta x} + k\Delta y\frac{T_{18}^{i}-T_{17}^{i}}{\Delta x} + k\Delta x\frac{T_{12}^{i}-T_{17}^{i}}{\Delta y} + k\Delta x\frac{T_{22}^{i}-T_{17}^{i}}{\Delta y} = \rho\Delta x\Delta y C\,\frac{T_{17}^{i+1}-T_{17}^{i}}{\Delta t}$$

$$T_{17}^{i+1} = ((\, k\Delta y\frac{T_{16}^{i}-T_{17}^{i}}{\Delta x} + k\Delta y\frac{T_{18}^{i}-T_{17}^{i}}{\Delta x} + k\Delta x\frac{T_{12}^{i}-T_{17}^{i}}{\Delta y} + k\Delta x\frac{T_{22}^{i}-T_{17}^{i}}{\Delta y})\ \frac{\Delta t}{\rho C\Delta x\Delta y}\,) +\ T_{17}^{i}$$

T[17][i+1] = (((k*y*(T[16][i]-T[17][i])/x)+ (k*y*(T[18][i]-T[17][i])/x)+(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:

$$k\Delta y\frac{T_{17}^{i}-T_{18}^{i}}{\Delta x} + k\Delta y\frac{T_{19}^{i}-T_{18}^{i}}{\Delta x} + k\Delta x\frac{T_{13}^{i}-T_{18}^{i}}{\Delta y} + k\Delta x\frac{T_{23}^{i}-T_{18}^{i}}{\Delta y} = \rho\Delta x\Delta y C\,\frac{T_{18}^{i+1}-T_{18}^{i}}{\Delta t}$$

$$T_{18}^{i+1} = ((k\Delta y\frac{T_{17}^{i}-T_{18}^{i}}{\Delta x} + k\Delta y\frac{T_{19}^{i}-T_{18}^{i}}{\Delta x} + k\Delta x\frac{T_{13}^{i}-T_{18}^{i}}{\Delta y} + k\Delta x\frac{T_{23}^{i}-T_{18}^{i}}{\Delta y}\,)\ \frac{\Delta t}{\rho C\Delta x\Delta y}\,) +\ T_{18}^{i}$$

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T[18][i+1] = (((k*y*(T[17][i]-T[18][i])/x)+ (k*y*(T[19][i]-T[18][i])/x)+(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:

$$hi\Delta y(T_h - T_{19}^i) + k\Delta y\frac{T_{18}^i - T_{19}^i}{\Delta x} + k\frac{\Delta x}{2}\frac{T_{14}^i - T_{19}^i}{\Delta y} + k\frac{\Delta x}{2}\frac{T_{24}^i - T_{19}^i}{\Delta y} = \rho\frac{\Delta x}{2}\Delta y C\frac{T_{19}^{i+1} - T_{19}^i}{\Delta t}$$

$$T_{19}^{i+1} = ((hi\Delta y(T_h - T_{19}^i) + k\Delta y\frac{T_{18}^i - T_{19}^i}{\Delta x} + k\frac{\Delta x}{2}\frac{T_{14}^i - T_{19}^i}{\Delta y} + k\frac{\Delta x}{2}\frac{T_{24}^i - T_{19}^i}{\Delta y})\ \frac{2\Delta t}{\rho C\Delta x\Delta y}) + T_{19}^i$$

T[19][i+1] = (((hi*y*(Th-T[19][i]))+(k*y*(T[18][i]-T[19][i])/x)+ (0.5*k*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:

$$ho\frac{\Delta x}{2}(T_\infty - T_{20}^i) + ho\frac{\Delta y}{2}(T_\infty - T_{20}^i) + k\frac{\Delta y}{2}\frac{T_{21}^i - T_{20}^i}{\Delta x} + k\frac{\Delta x}{2}\frac{T_{15}^i - T_{20}^i}{\Delta y} = \rho\frac{\Delta x}{2}\frac{\Delta y}{2}C\frac{T_{20}^{i+20} - T_{20}^i}{\Delta t}$$

$$T_{20}^{i+20} = ((ho\frac{\Delta x}{2}(T_\infty - T_{20}^i) + ho\frac{\Delta y}{2}(T_\infty - T_{20}^i) + k\frac{\Delta y}{2}\frac{T_{21}^i - T_{20}^i}{\Delta x} + k\frac{\Delta x}{2}\frac{T_{15}^i - T_{20}^i}{\Delta y})\ \frac{4\Delta t}{\rho C\Delta x\Delta y}) + T_{20}^i$$

T[20][i+1] = (((0.5*ho*x*(Ta-T[20][i]))+(0.5*ho*y*(Ta-T[20][i]))+(0.5*k*y*(T[21][i]-T[20][i])/x)+ (0.5*k*x*(T[15][i]-T[20][i])/y))*((4*t)/(r*c*x*y))) +T[20][i];

Node 21:

$$ho\Delta x(T_\infty - T_{21}^i) + k\frac{\Delta y}{2}\frac{T_{20}^i - T_{21}^i}{\Delta x} + k\frac{\Delta y}{2}\frac{T_{22}^i - T_{21}^i}{\Delta x} + k\Delta x\frac{T_{16}^i - T_{21}^i}{\Delta y} = \rho\Delta x\frac{\Delta y}{2}C\frac{T_{21}^{i+1} - T_{21}^i}{\Delta t}$$

$$T_{21}^{i+1} = ((ho\Delta x(T_\infty - T_{21}^i) + k\frac{\Delta y}{2}\frac{T_{20}^i - T_{21}^i}{\Delta x} + k\frac{\Delta y}{2}\frac{T_{22}^i - T_{21}^i}{\Delta x} + k\Delta x\frac{T_{16}^i - T_{21}^i}{\Delta y})\ \frac{2\Delta t}{\rho C\Delta x\Delta y}) + T_{21}^i$$

T[21][i+1] = (((0.5*ho*x*(Ta-T[21][i]))+(0.5*k*y*(T[20][i]-T[21][i])/x)+(0.5*k*y*(T[22][i]-T[21][i])/x)+ (k*x*(T[16][i]-T[21][i])/y))*((2*t)/(r*c*x*y))) +T[21][i];

Node 22:

$$ho\Delta x(T_\infty - T_{22}^i) + k\frac{\Delta y}{2}\frac{T_{21}^i - T_{22}^i}{\Delta x} + k\frac{\Delta y}{2}\frac{T_{23}^i - T_{22}^i}{\Delta x} + k\Delta x\frac{T_{17}^i - T_{22}^i}{\Delta y} = \rho\Delta x\frac{\Delta y}{2}C\frac{T_{22}^{i+1} - T_{22}^i}{\Delta t}$$

$$T_{22}^{i+1} = ((ho\Delta x(T_\infty - T_{22}^i) + k\frac{\Delta y}{2}\frac{T_{21}^i - T_{22}^i}{\Delta x} + k\frac{\Delta y}{2}\frac{T_{23}^i - T_{22}^i}{\Delta x} + k\Delta x\frac{T_{17}^i - T_{22}^i}{\Delta y})\ \frac{2\Delta t}{\rho C\Delta x\Delta y}) + T_{22}^i$$

T[22][i+1] = (((ho*x*(Ta-T[22][i]))+(0.5*k*y*(T[21][i]-T[22][i])/x)+(0.5*k*y*(T[23][i]-T[22][i])/x)+ (k*x*(T[17][i]-T[22][i])/y))*((2*t)/(r*c*x*y)))
+T[22][i];

Node 23:

$$ho\Delta x(T_\infty - T_{23}^i) + k\frac{\Delta y}{2}\frac{T_{22}^i - T_{23}^i}{\Delta x} + k\frac{\Delta y}{2}\frac{T_{24}^i - T_{23}^i}{\Delta x} + k\Delta x\frac{T_{18}^i - T_{23}^i}{\Delta y} = \rho\Delta x\frac{\Delta y}{2}C\frac{T_{23}^{i+1} - T_{23}^i}{\Delta t}$$

$$T_{23}^{i+1} = ((ho\Delta x(T_\infty - T_{23}^i) + k\frac{\Delta y}{2}\frac{T_{22}^i - T_{23}^i}{\Delta x} + k\frac{\Delta y}{2}\frac{T_{24}^i - T_{23}^i}{\Delta x} + k\Delta x\frac{T_{18}^i - T_{23}^i}{\Delta y})\ \frac{2\Delta t}{\rho C\Delta x\Delta y}) + T_{23}^i$$

T[23][i+1] = (((ho*x*(Ta-T[23][i]))+(0.5*k*y*(T[22][i]-T[23][i])/x)+(0.5*k*y*(T[24][i]-T[23][i])/x)+ (k*x*(T[18][i]-T[23][i])/y))*((2*t)/(r*c*x*y))) +T[23][i];

Node 24:

$$ho\frac{\Delta x}{2}(T_\infty - T_{24}^i) + hi\frac{\Delta y}{2}(T_h - T_{24}^i) + k\frac{\Delta y}{2}\frac{T_{23}^i - T_{24}^i}{\Delta x} + k\frac{\Delta x}{2}\frac{T_{19}^i - T_{24}^i}{\Delta y} = \rho\frac{\Delta x}{2}\frac{\Delta y}{2}C\frac{T_{24}^{i+1} - T_{24}^i}{\Delta t}$$

$$T_{24}^{i+1} = ((ho\frac{\Delta x}{2}(T_\infty - T_{24}^i) + hi\frac{\Delta y}{2}(T_h - T_{24}^i) + k\frac{\Delta y}{2}\frac{T_{23}^i - T_{24}^i}{\Delta x} + k\frac{\Delta x}{2}\frac{T_{19}^i - T_{24}^i}{\Delta y})\ \frac{4\Delta t}{\rho C\Delta x\Delta y}) + T_{24}^i$$

T[24][i+1] = (((0.5*ho*x*(Ta-T[24][i]))+(0.5*hi*y*(Th-T[24][i])) +(0.5*k*y*(T[23][i]-T[24][i])/x)+ (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 resolve the matrix created by finite difference equations for 24 nodes. We can compute temperature distribution and stress distribution with respect to time.

COMPUTER PROGRAM

```
#include<iostream.h>
#include<conio.h>
#include<math.h>
#include<complex.h>
```

```
#include<fstream.h>
void main()
{ clrscr;
ofstreammyfile;
myfile.open ("outputfdm.txt");
myfile<<"Writing this to a file.\n";
float T[25][500];
float S[25][500];
float hi,ho,ha,To,r,t,k,Ta,c,Th,E,Af,Sut,Se,m,N,L;
cout<<"Enter in W/m2 K value of hi";
cin>>hi;
cout<<"Enter in W/m2 K value of ho";
cin>>ho;
cout<<"Enter in W/m2 K value of ha";
cin>>ha;
cout<<"Enter in Kg/m3 value of density";
cin>>r;
cout<<"Enter in seconds time interval delta t";
cin>>t;
cout<<"Enter in W/m K value of thermal conductivity";
cin>>k;
cout<<"Enter in Kelvin Temperature outside Furnace Wall";
cin>>Ta;
cout<<"Enter in Kelvin Temperature inside Furnace Wall";
cin>>Th;
cout<<"Enter in Kelvin Temperature of Air";
cin>>To;
cout<<"Enter in J/Kg K value of Specific Heat";
cin>>c;
cout<<"Enter in N/m2 value of Elasticity Constant";
cin>>E;
cout<<"Enter in m/K Thermal Expansion Co-efficient";
cin>>Af;
cout<<"Enter in MPA value of Ultimate Stress";
cin>>Sut;
T[1][0]=300;
T[2][0]=300;
T[3][0]=300;
T[4][0]=300;
T[5][0]=300;
T[6][0]=300;
T[7][0]=300;
T[8][0]=300;
T[9][0]=300;
T[10][0]=300;
T[11][0]=300;
T[12][0]=300;
T[13][0]=300;
T[14][0]=300;
T[15][0]=300;
T[16][0]=300;
T[17][0]=300;
T[18][0]=300;
T[19][0]=300;
T[20][0]=300;
T[21][0]=300;
T[22][0]=300;
T[23][0]=300;
T[24][0]=300;
for (inti=0; i<=270;i++)
{
T[1][i+1] = (((0.5*ha*0.06*(To-T[1][i])) +(ho*0.3*(Ta-T[1][i])/2)+(0.5*k*0.3*(T[2][i]-T[1][i])/0.06)+(0.5*k*0.06*(T[4][i]-T[1][i])/0.3)
)*((4*t)/(r*c*0.06*0.3)))+T[1][i];
T[2][i+1] = (((ha*0.06*(To-T[2][i]))+(0.5*k*0.3*(T[1][i]-T[2][i])/0.06)+(0.5*k*0.3*(T[3][i]-T[2][i])/0.06) +(0.5*k*0.06*(T[5][i]-
T[2][i])/0.3))*((2*t)/(r*c*0.06*0.3)))+T[2][i];
T[3][i+1] = (((ha*0.06*(To-T[3][i])*0.5) +( hi*0.3*(Th-T[3][i])*0.5 ) +(0.5*k*0.3*(T[2][i]-T[3][i])/0.06)+(0.5*k*0.06*(T[6][i]-
T[3][i])/0.3)) *((4*t)/(r*c*0.06*0.3)))+T[3][i];
T[4][i+1] = ((( ho*0.3*(Ta-T[4][i])) +(k*0.3*(T[5][i]-T[4][i])/0.06)+(0.5*k*0.06*(T[1][i]-T[4][i])/0.3) + (0.5*k*0.06*(T[7][i]-
T[4][i])/0.3)) *((2*t)/(r*c*0.06*0.3)))+T[4][i];
T[5][i+1] = (((k*0.3*(T[4][i]-T[5][i])/0.06)+(k*0.3*(T[6][i]-T[5][i])/0.06) + (k*0.06*(T[8][i]-T[5][i])/0.3)) *((t)/(r*c*0.06*0.3)))+T[5][i];
T[6][i+1] = (((hi*0.3*(Th-T[6][i])) + (k*0.3*(T[2][i]-T[6][i])/0.06)+(0.5*k*0.06*(T[3][i]-T[6][i])/0.3) + (0.5*k*0.06*(T[9][i]-
T[6][i])/0.3)) *((2*t)/(r*c*0.06*0.3)))+T[6][i];
```

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```
T[7][i+1] = (((ho*0.3*(Ta-T[7][i])) + (k*0.3*(T[8][i]-T[7][i])/0.06)+(0.5*k*0.06*(T[4][i]-T[7][i])/0.3) + (0.5*k*0.06*(T[10][i]-T[7][i])/0.3)) *((2*t)/(r*c*0.06*0.3)))+T[7][i];
T[8][i+1] = (((k*0.3*(T[7][i]-T[8][i])/0.06)+( k*0.3*(T[9][i]-T[8][i])/0.06 ) +(k*0.06*(T[5][i]-T[8][i])/0.3) + (k*0.06*(T[11][i]-T[8][i])/0.3)) *((t)/(r*c*0.06*0.3)))+T[8][i];
T[9][i+1] = (( (hi*0.3*(Th-T[9][i]))+(k*0.3*(T[8][i]-T[9][i])/0.06)+ (0.5*k*0.06*(T[6][i]-T[9][i])/0.3) + (0.5*k*0.06*(T[12][i]-T[9][i])/0.3)) *((2*t)/(r*c*0.06*0.3)))+T[9][i];
T[10][i+1] = (( (ho*0.18*(Ta-T[10][i]))+(k*0.18*(T[11][i]-T[10][i])/0.06)+ (0.5*k*0.06*(T[7][i]-T[10][i])/0.18) + (0.5*k*0.06*(T[15][i]-T[10][i])/0.18)) *((2*t)/(r*c*0.06*0.18)))+T[10][i];
T[11][i+1] = (( (k*0.18*(T[10][i]-T[11][i])/0.06)+ (k*0.18*(T[12][i]-T[11][i])/0.06)+ (k*0.06*(T[8][i]-T[11][i])/0.18) + (k*0.06*(T[16][i]-T[11][i])/0.18)) *((t)/(r*c*0.06*0.18)))+T[11][i];
T[12][i+1] = (( (0.5*hi*0.12*(Th-T[12][i]))+( 0.5*hi*0.18*(Th-T[12][i])) +(k*0.18*(T[11][i]-T[12][i])/0.12)+ (0.5*k*0.18*(T[13][i]-T[12][i])/0.12)+(0.5*k*0.12*(T[9][i]-T[12][i])/0.18) + (k*0.12*(T[17][i]-T[12][i])/0.18)) *((4*t)/(3*r*c*0.12*0.18))) +T[12][i];
T[13][i+1] = (( (hi*0.18*(Th-T[13][i]))+(0.5*k*0.18*(T[12][i]-T[13][i])/0.18)+ (0.5*k*0.18*(T[14][i]-T[13][i])/0.18)+ (k*0.18*(T[18][i]-T[13][i])/0.18)) *((2*t)/(r*c*0.18*0.18)))+T[13][i];
T[14][i+1] = (( (0.5*hi*0.18*(Th-T[14][i]))+(0.5*hi*0.18*(Th-T[14][i])) +(0.5*k*0.18*(T[13][i]-T[14][i])/0.18)+ (0.5*k*0.18*(T[19][i]-T[14][i])/0.18)) *((4*t)/(r*c*0.18*0.18)))+T[14][i];
T[15][i+1] = (( (ho*0.06*(Ta-T[15][i]))+(k*0.06*(T[16][i]-T[15][i])/0.06)+ (0.5*k*0.06*(T[10][i]-T[15][i])/0.06)+( 0.5*k*0.06*(T[20][i]-T[15][i])/0.06)) *((2*t)/(r*c*0.06*0.06)))+T[15][i];
T[16][i+1] = (( (k*0.06*(T[15][i]-T[16][i])/0.06)+ (k*0.06*(T[17][i]-T[16][i])/0.06 )+(k*0.06*(T[11][i]-T[16][i])/0.06)+( k*0.06*(T[21][i]-T[16][i])/0.06)) *((t)/(r*c*0.06*0.06)))+T[16][i];
T[17][i+1] = (( (k*0.06*(T[16][i]-T[17][i])/0.12)+ (k*0.06*(T[18][i]-T[17][i])/0.12 )+(k*0.12*(T[12][i]-T[17][i])/0.06)+( k*0.12*(T[22][i]-T[17][i])/0.06)) *((t)/(r*c*0.12*0.06)))+T[17][i];
T[18][i+1] = (( (k*0.06*(T[17][i]-T[18][i])/0.18)+ (k*0.06*(T[19][i]-T[18][i])/0.18 )+(k*0.18*(T[13][i]-T[18][i])/0.06)+( k*0.18*(T[23][i]-T[18][i])/0.06)) *((t)/(r*c*0.18*0.06)))+T[18][i];
T[19][i+1] = (( (hi*0.06*(Th-T[19][i]))+(k*0.06*(T[18][i]-T[19][i])/0.18)+ (0.5*k*0.18*(T[14][i]-T[19][i])/0.06)+( 0.5*k*0.18*(T[24][i]-T[19][i])/0.06)) *((2*t)/(r*c*0.18*0.06)))+T[19][i];
T[20][i+1] = (( (0.5*ho*0.06*(Ta-T[20][i]))+( 0.5*ho*0.06*(Ta-T[20][i]))+(0.5*k*0.06*(T[21][i]-T[20][i])/0.06)+ (0.5*k*0.06*(T[15][i]-T[20][i])/0.06))*((4*t)/(r*c*0.06*0.06)))+T[20][i];
T[21][i+1] = (( (0.5*ho*0.06*(Ta-T[21][i]))+(0.5*k*0.06*(T[20][i]-T[21][i])/0.06)+( 0.5*k*0.06*(T[22][i]-T[21][i])/0.06)+ (k*0.06*(T[16][i]-T[21][i])/0.06))*((2*t)/(r*c*0.06*0.06)))+T[21][i];
T[22][i+1] = (( (ho*0.12*(Ta-T[22][i]))+(0.5*k*0.06*(T[21][i]-T[22][i])/0.12)+( 0.5*k*0.06*(T[23][i]-T[22][i])/0.12)+ (k*0.12*(T[17][i]-T[22][i])/0.06))*((2*t)/(r*c*0.12*0.06)))+T[22][i];
T[23][i+1] = (( (ho*0.18*(Ta-T[23][i]))+(0.5*k*0.06*(T[22][i]-T[23][i])/0.18)+( 0.5*k*0.06*(T[24][i]-T[23][i])/0.18)+ (k*0.18*(T[18][i]-T[23][i])/0.06))*((2*t)/(r*c*0.18*0.06)))+T[23][i];
T[24][i+1] = (( (0.5*ho*0.18*(Ta-T[24][i]))+( 0.5*hi*0.06*(Th-T[24][i])) +(0.5*k*0.06*(T[23][i]-T[24][i])/0.18)+ (0.5*k*0.18*(T[19][i]-T[24][i])/0.06))*((4*t)/(r*c*0.18*0.06)))+T[24][i];
S[14][i] = E*Af*T[14][i];
}
for (i=271; i<=360;i++)
{
hi=ha;
Th=Ta;
T[1][i+1] = (((0.5*ha*0.06*(To-T[1][i])) +(ho*0.3*(Ta-T[1][i])/2)+(0.5*k*0.3*(T[2][i]-T[1][i])/0.06)+(0.5*k*0.06*(T[4][i]-T[1][i])/0.3) )*((4*t)/(r*c*0.06*0.3)))+T[1][i];
T[2][i+1] = (((ha*0.06*(To-T[2][i]))+(0.5*k*0.3*(T[1][i]-T[2][i])/0.06)+(0.5*k*0.3*(T[3][i]-T[2][i])/0.06) +(0.5*k*0.06*(T[5][i]-T[2][i])/0.3))*((2*t)/(r*c*0.06*0.3)))+T[2][i];
T[3][i+1] = (((ha*0.06*(To-T[3][i])*0.5) +( hi*0.3*(Th-T[3][i])*0.5 ) +(0.5*k*0.3*(T[2][i]-T[3][i])/0.06)+(0.5*k*0.06*(T[6][i]-T[3][i])/0.3)) *((4*t)/(r*c*0.06*0.3)))+T[3][i];
T[4][i+1] = ((( ho*0.3*(Ta-T[4][i])) +(k*0.3*(T[5][i]-T[4][i])/0.06)+(0.5*k*0.06*(T[1][i]-T[4][i])/0.3) + (0.5*k*0.06*(T[7][i]-T[4][i])/0.3)) *((2*t)/(r*c*0.06*0.3)))+T[4][i];
T[5][i+1] = (((k*0.3*(T[4][i]-T[5][i])/0.06)+(k*0.3*(T[6][i]-T[5][i])/0.06) + (k*0.06*(T[8][i]-T[5][i])/0.3)) *((t)/(r*c*0.06*0.3)))+T[5][i];
T[6][i+1] = (((hi*0.3*(Th-T[6][i])) + (k*0.3*(T[2][i]-T[6][i])/0.06)+(0.5*k*0.06*(T[3][i]-T[6][i])/0.3) + (0.5*k*0.06*(T[9][i]-T[6][i])/0.3)) *((2*t)/(r*c*0.06*0.3)))+T[6][i];
T[7][i+1] = (((ho*0.3*(Ta-T[7][i])) + (k*0.3*(T[8][i]-T[7][i])/0.06)+(0.5*k*0.06*(T[4][i]-T[7][i])/0.3) + (0.5*k*0.06*(T[10][i]-T[7][i])/0.3)) *((2*t)/(r*c*0.06*0.3)))+T[7][i];
T[8][i+1] = (((k*0.3*(T[7][i]-T[8][i])/0.06)+( k*0.3*(T[9][i]-T[8][i])/0.06 ) +(k*0.06*(T[5][i]-T[8][i])/0.3) + (k*0.06*(T[11][i]-T[8][i])/0.3)) *((t)/(r*c*0.06*0.3)))+T[8][i];
T[9][i+1] = (( (hi*0.3*(Th-T[9][i]))+(k*0.3*(T[8][i]-T[9][i])/0.06)+ (0.5*k*0.06*(T[6][i]-T[9][i])/0.3) + (0.5*k*0.06*(T[12][i]-T[9][i])/0.3)) *((2*t)/(r*c*0.06*0.3)))+T[9][i];
T[10][i+1] = (( (ho*0.18*(Ta-T[10][i]))+(k*0.18*(T[11][i]-T[10][i])/0.06)+ (0.5*k*0.06*(T[7][i]-T[10][i])/0.18) + (0.5*k*0.06*(T[15][i]-T[10][i])/0.18)) *((2*t)/(r*c*0.06*0.18)))+T[10][i];
T[11][i+1] = (( (k*0.18*(T[10][i]-T[11][i])/0.06)+ (k*0.18*(T[12][i]-T[11][i])/0.06)+ (k*0.06*(T[8][i]-T[11][i])/0.18) + (k*0.06*(T[16][i]-T[11][i])/0.18)) *((t)/(r*c*0.06*0.18)))+T[11][i];
T[12][i+1] = (( (0.5*hi*0.12*(Th-T[12][i]))+( 0.5*hi*0.18*(Th-T[12][i])) +(k*0.18*(T[11][i]-T[12][i])/0.12)+ (0.5*k*0.18*(T[13][i]-T[12][i])/0.12)+(0.5*k*0.12*(T[9][i]-T[12][i])/0.18) + (k*0.12*(T[17][i]-T[12][i])/0.18)) *((4*t)/(3*r*c*0.12*0.18))) +T[12][i];
T[13][i+1] = (( (hi*0.18*(Th-T[13][i]))+(0.5*k*0.18*(T[12][i]-T[13][i])/0.18)+ (0.5*k*0.18*(T[14][i]-T[13][i])/0.18)+ (k*0.18*(T[18][i]-T[13][i])/0.18)) *((2*t)/(r*c*0.18*0.18)))+T[13][i];
T[14][i+1] = (( (0.5*hi*0.18*(Th-T[14][i]))+(0.5*hi*0.18*(Th-T[14][i])) +(0.5*k*0.18*(T[13][i]-T[14][i])/0.18)+ (0.5*k*0.18*(T[19][i]-T[14][i])/0.18)) *((4*t)/(r*c*0.18*0.18)))+T[14][i];
T[15][i+1] = (( (ho*0.06*(Ta-T[15][i]))+(k*0.06*(T[16][i]-T[15][i])/0.06)+ (0.5*k*0.06*(T[10][i]-T[15][i])/0.06)+( 0.5*k*0.06*(T[20][i]-T[15][i])/0.06)) *((2*t)/(r*c*0.06*0.06)))+T[15][i];
T[16][i+1] = (( (k*0.06*(T[15][i]-T[16][i])/0.06)+ (k*0.06*(T[17][i]-T[16][i])/0.06 )+(k*0.06*(T[11][i]-T[16][i])/0.06)+( k*0.06*(T[21][i]-T[16][i])/0.06)) *((t)/(r*c*0.06*0.06)))+T[16][i];
```

```
T[17][i+1] = (( (k*0.06*(T[16][i]-T[17][i])/0.12)+ (k*0.06*(T[18][i]-T[17][i])/0.12 )+(k*0.12*(T[12][i]-T[17][i])/0.06)+( k*0.12*(T[22][i]-T[17][i])/0.06)) *((t)/(r*c*0.12*0.06)))+T[17][i];
T[18][i+1] = (( (k*0.06*(T[17][i]-T[18][i])/0.18)+ (k*0.06*(T[19][i]-T[18][i])/0.18 )+(k*0.18*(T[13][i]-T[18][i])/0.06)+( k*0.18*(T[23][i]-T[18][i])/0.06)) *((t)/(r*c*0.18*0.06)))+T[18][i];
T[19][i+1] = (( (hi*0.06*(Th-T[19][i]))+(k*0.06*(T[18][i]-T[19][i])/0.18)+ (0.5*k*0.18*(T[14][i]-T[19][i])/0.06)+( 0.5*k*0.18*(T[24][i]-T[19][i])/0.06)) *((2*t)/(r*c*0.18*0.06)))+T[19][i];
T[20][i+1] = (( (0.5*ho*0.06*(Ta-T[20][i]))+( 0.5*ho*0.06*(Ta-T[20][i]))+(0.5*k*0.06*(T[21][i]-T[20][i])/0.06)+ (0.5*k*0.06*(T[15][i]-T[20][i])/0.06))*((4*t)/(r*c*0.06*0.06)))+T[20][i];
T[21][i+1] = (( (0.5*ho*0.06*(Ta-T[21][i]))+(0.5*k*0.06*(T[20][i]-T[21][i])/0.06)+( 0.5*k*0.06*(T[22][i]-T[21][i])/0.06)+ (k*0.06*(T[16][i]-T[21][i])/0.06))*((2*t)/(r*c*0.06*0.06)))+T[21][i];
T[22][i+1] = (( (ho*0.12*(Ta-T[22][i]))+(0.5*k*0.06*(T[21][i]-T[22][i])/0.12)+( 0.5*k*0.06*(T[23][i]-T[22][i])/0.12)+ (k*0.12*(T[17][i]-T[22][i])/0.06))*((2*t)/(r*c*0.12*0.06)))+T[22][i];
T[23][i+1] = (( (ho*0.18*(Ta-T[23][i]))+(0.5*k*0.06*(T[22][i]-T[23][i])/0.18)+( 0.5*k*0.06*(T[24][i]-T[23][i])/0.18)+ (k*0.18*(T[18][i]-T[23][i])/0.06))*((2*t)/(r*c*0.18*0.06)))+T[23][i];
T[24][i+1] = (( (0.5*ho*0.18*(Ta-T[24][i]))+( 0.5*hi*0.06*(Th-T[24][i])) +(0.5*k*0.06*(T[23][i]-T[24][i])/0.18)+ (0.5*k*0.18*(T[19][i]-T[24][i])/0.06))*((4*t)/(r*c*0.18*0.06)))+T[24][i];
S[14][i] = E*Af*T[14][i];
 }
for(i=0; i<=360;i=i+6)
{
myfile<<"MAXIMUM TEMPERATURE AFTER  "<<i/6<<" MINUTES"<<T[14][i]<<" KELVIN"<<endl;
myfile<<"MAXIMUM STRESS AFTER  "<<i/6<<" MINUTES "<<S[14][i]<<" MPa"<<endl;          }
(i=0; i<=300; i++)
{
if (i==270)
{
myfile<<"S"<<S[14][i];
Se=0.15*Sut;
m = (Sut-Se)/7;
N = 7 -((S[14][i]-Se)/m);
L = pow(10,N);
myfile<<"N"<<N;
myfile<<"LIFE CYCLE"<<L;
myfile.close();
}
}getch();  }
```

IV. RESULTS AND DISCUSSION

Stress-Life Method

To determine life of any component by Stress-Life Method, we need to find out ultimate strength and endurance limit of the component for the required material.

We know the values of ultimate stress for these all materials. Zirconiais having ultimate strength of 600 MPa. We can find out Se' from the equation given below or we can say dividing value of ultimate strength.

We know value of ultimate stress of zirconia is 600 Mpa.

We know the relation between Sut and Se' so that we can find out Se'.

$Se' = 0.5 * Sut = 300$ MPa

Endurance Limit Modifying Factors

We have seen that the rotating-beam specimen used in the laboratory to determine endurance limits is prepared very carefully and tested under closely controlled conditions.

It is unrealistic to expect the endurance limit of a mechanical or structural member to match the values obtained in the laboratory.

Some differences include

Material: composition, basis of failure, variability
Manufacturing: method, heat treatment, fretting corrosion, surface condition, stress concentration
Environment: corrosion, temperature, stress state, relaxation times
Design: size, shape, life, stress state, stress concentration, speed, fretting, galling

Marin identified factors that quantified the effects of surface condition, size, loading, temperature, and miscellaneous items. The question of whether to adjust the endurance limit by subtractive corrections or multiplicative corrections was resolved by an extensive statistical analysis of a 4340 (electric furnace, aircraft quality) steel, in which a correlation coefficient of 0.85 was found for the multiplicative form and 0.40 for the additive form.

A Marin equation is therefore written as

Se = ka*kb*kc*kd*ke*kf* Se'
Where,
ka= surface condition modification factor = 0.84
kb= size modification factor = 0.98
kc= load modification factor = 0.96
kd= temperature modification factor = 0.45
ke= reliability factor = 0.9
kf= miscellaneous-effects modification factor = 0.95
Se'= specimen endurance limit
Se = endurance limit at the critical location of a machine part in the geometry and condition of use.
We can find out different factor like surface finish factor, size factor, loading factor, temperature factor, reliability factor, miscellaneous effects factor as per the guideline. (Joseph E. Shigley*et al*, Machine Engineering Design)
Now, we can find out endurance limit for all different materials.
Se = ka*kb*kc*kd*ke*kf*Se' = 100MPa

In figure 2, Stress – Log N curve is plotted which is utilized for prediction of existence cycle of induction furnace wall for silica ramming mass as it is requirement of stress existence methodology. Stress – Log N curve for silica ramming mass is produced with the help of ultimate stress 500 MPa and endurance limit 75 MPa which is determined making use of endurance enhancing reasons. Maximum stress created in the induction furnace refractory wall for silica ramming mass is 356.27 MPa which is found from the output of computer program made to resolve developed mathematical model. We generate a horizontal line from 356.27 MPa and the place it cut the Stress – Log N curve we take it within the vertical direction and discovered value of Log N as 2.367. From answer of Log N, we can in finding value of N equal to 232 reversible stress cycles. For this reason, we are able to derive from Stress – Log N graph that life cycle of induction furnace refractory wall made up of silica ramming mass is 232 stress cycles.

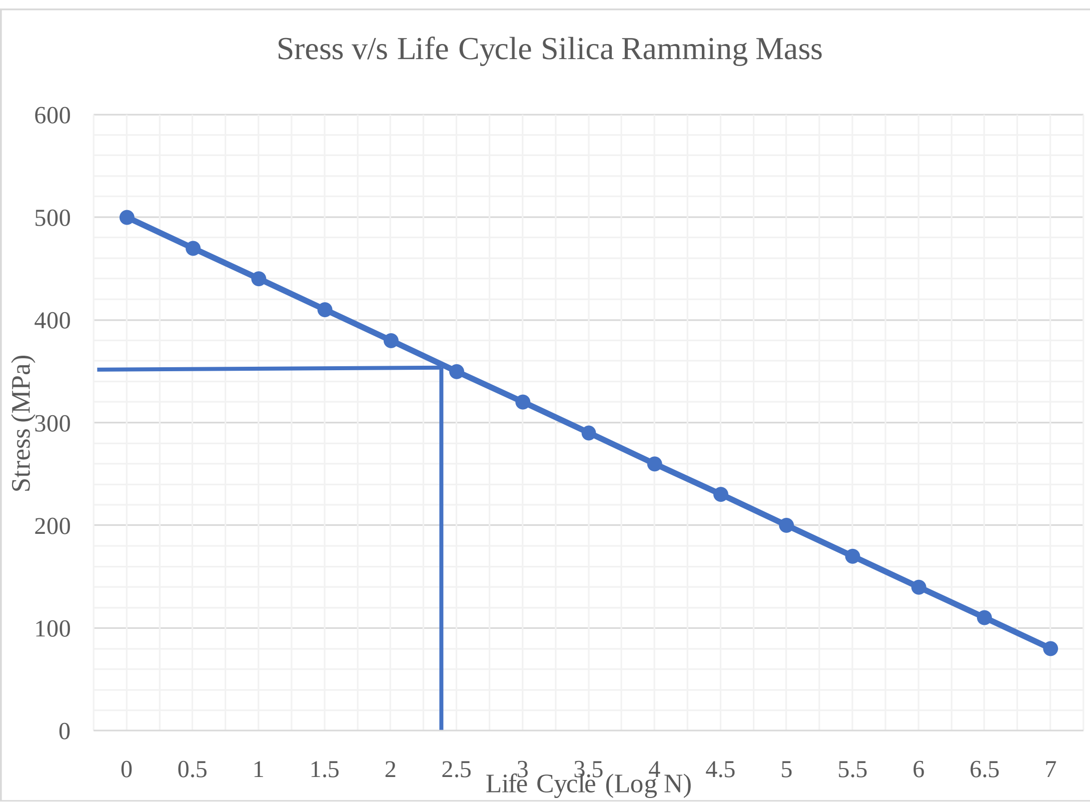

Figure 2 Stress v/s Life Cycle Graph for Silica Ramming Mass

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In figure 3, Stress – Log N curve is plotted which is utilized for prediction of existence cycle of induction furnace wall for alumina ramming mass as it is requirement of stress existence methodology. Stress – Log N curve for alumina ramming mass is produced with the help of ultimate strength 500 MPa and endurance limit 75 MPa which is observed utilizing endurance enhancing factors. Highest stress created within the induction furnace refractory wall for alumina ramming mass is 345.75 MPa which is found from the output of computer application made to resolve advanced mathematical model. We generate a horizontal line from 345.75MPa and the place it cut the Stress – Log N curve we take it in the vertical course and located value of Log N as 2.54. From answer of Log N, we are able to find value of N equal to 347 reversible stress cycles. For that reason, we are able to derive from Stress – Log N graph that life cycle of induction furnace refractory wall made from alumina ramming mass is 347 stress cycles.

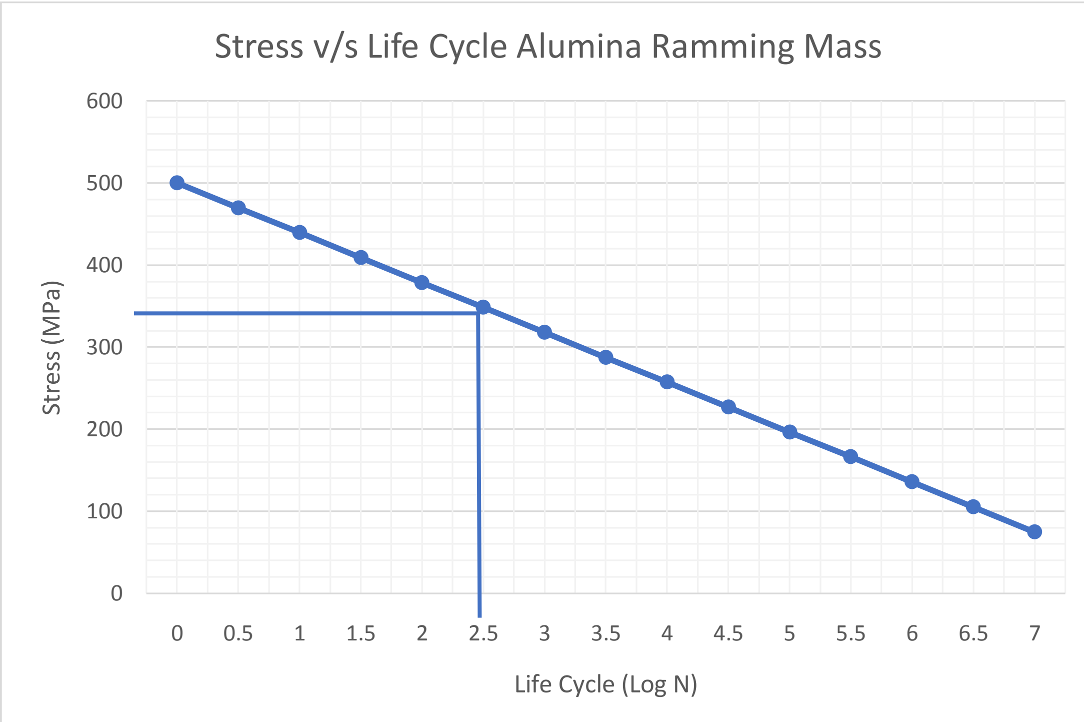

Figure 3 Stress v/s Life Cycle Graph for Alumina Ramming Mass

In figure4, Stress – Log N curve is plotted which is utilized for prediction of existence cycle of induction furnace wall for magnesia ramming mass as it is requirement of stress existence methodology. Stress – Log N curve for magnesia ramming mass is produced with the support of ultimatestress 600 MPa and endurance limit 90 MPa which is observed utilizing endurance enhancing details. Maximum stress created in the induction furnace refractory wall for magnesia ramming mass is 413.97MPa which is determined from the output of computer application made to solve advanced mathematical model. We generate a horizontal line from 413.97MPa and where it cut the Stress – Log N curve we take it in the vertical course and determined value of Log N as 2.55. From response of Log N, we can in finding value of N equal to 357 reversible stress cycles. Consequently, we can derive from Stress – Log N graph that life cycle of induction furnace refractory wall made from magnesia ramming mass is 357 stress cycles.

In figure 5, Stress – Log N curve is plotted which is utilized for prediction of life cycle of induction furnace wall for zirconia as it is requirement of stress existence methodology. Stress – Log N curve for zirconia is produced with the ultimate strength 600 MPa and endurance limit 90 MPa which is observed utilizing endurance modifying details. Maximum stress created in the induction furnace refractory wall for zirconia is 377.34 MPa which is located from the output of computer application made to solve developed mathematical model. We generate a horizontal line from 377.34 MPa and where it cut the Stress – Log N curve we take it in the vertical course and located value of Log N as 3.05. From answer of Log N, we can to find value of N equal to 1137 reversible stress cycles. For this reason, we are able to derive from Stress – Log N graph that life cycle of induction furnace refractory wall made from zirconia is 1137 stress cycles.

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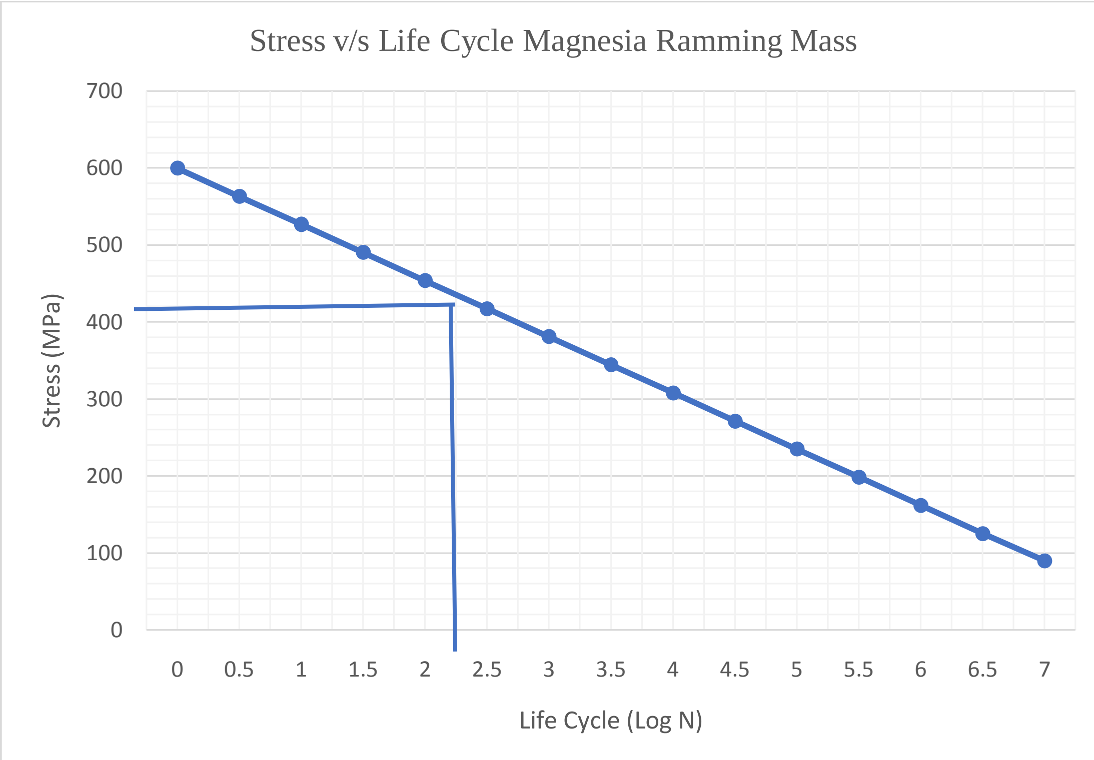

Figure 4 Stress v/s Life Cycle Graph for Magnesia Ramming Mass

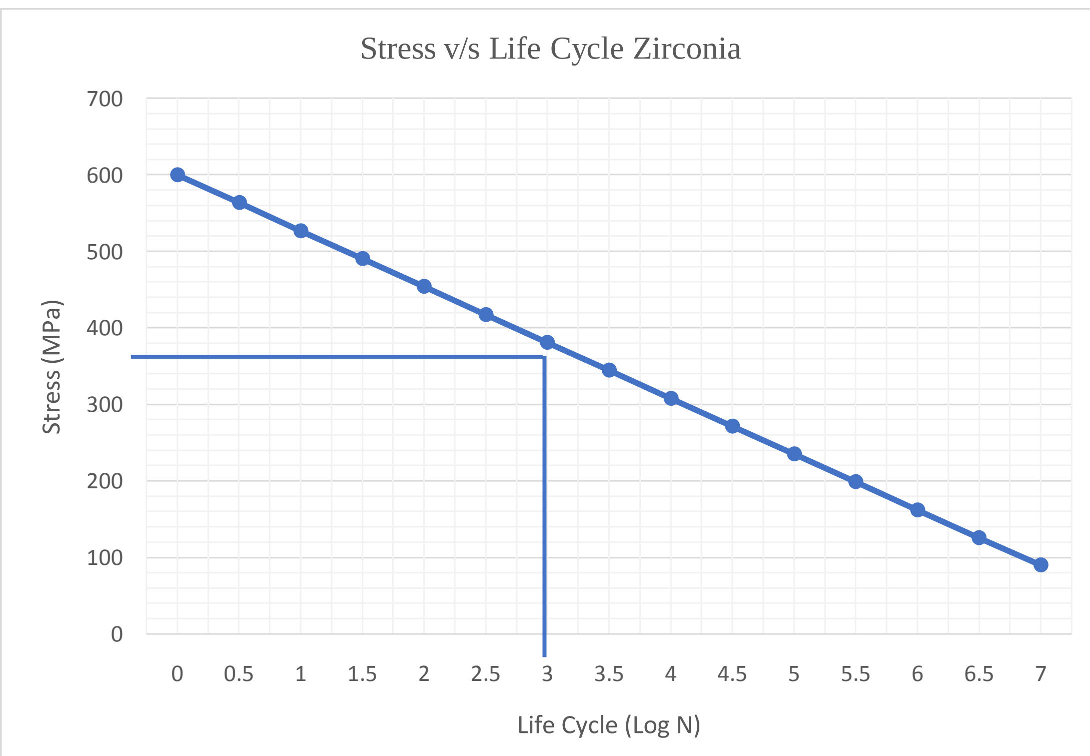

Figure 5 Stress v/s Life Cycle Graph for Zirconia

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CONCLUSION

Induction Melting Furnaces are incredibly used now- a-days for melting of different kinds of substances. It is going to disturb production time table because it requires time to exchange the induction melting furnace wall of silica ramming mass, alumina ramming mass, magnesia ramming mass or zirconia. Finite difference evaluation is completed for induction melting furnace refractory wall and validation is completed with recognize to experimental results. Specific finite difference evaluation is done with admire to genuine working conditions of induction furnace and material properties of silica ramming mass, alumina ramming mass, magnesia ramming mass or zirconia. Then S – log N Curves are plotted for Life Span Prediction. From the outcome of experimental gain knowledge of and specific finite change evaluation of thermal fatigue failure of induction melting furnace wall, it may be obvious that finite change model precisely predicts the failure of the induction furnace refractory wall and the specific solution stipulations within the finite difference numerical calculation are accurate. The fatigue life of the induction melting furnace refractory wall below thermal fatigue working conditions used to be estimated utilizing stress-existence method through plotting S – log N curves for silica ramming mass, alumina ramming mass, magnesia ramming mass or zirconia on the foundation of explicit finite difference calculations and maximum thermal stress in the induction melting furnace refractory wall. We can use it as a linear to develop lifespan or we are able to use premixed silica ramming mass, alumina ramming mass, magnesia ramming mass or zirconia for low-cost and higher working lifespan of induction melting furnace wall. The accuracy of the fatigue life prediction for the induction melting furnace refractory wall is dependent upon temperature and thermal stress spectrum calculated on the vigorous factor by means of finite change procedure and S-log N curves prepared from the material properties and boundary conditionsfor silica ramming mass, alumina ramming mass, magnesia ramming mass or zirconia.

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