# Numerical investigation of heat transfer process form with constant heat flux in exothermic board by natural convection inside a closed cavity

Behnaz Arjoman Kermani ,Islamic Azad university , branch of Bardsir

***Abstract:*** Natural Convection process within a closed cavity when heat source is on the vertical wall of it special importance .heat source generate constant heat flux. A common practical example of this case is electronic boards inside a computer or radiator in the room. One of the important parameters in designing electronic boards in the computer or another things is the maximum temperature of pieces; therefore we must examine the factors that affect this to have a reduced the maximum temperature. Governing equations on fluid flow mass, velocity and energy equations using the finite element method with power law, pr = 0.7, a non-uniform network is converted to algebraic form.

Because of buoyancy force the Momentum equation depended on temperature. Momentum equations and energy equation are solved simultaneously. Momentum equations that include unknown pressure solve with Simple algorithm. The velocities are obtained from Momentum equation must satisfy continuity equation. Heat generation is constant. Wall's temperature is $T_\infty$ (temperature of environment). At first velocity of fluid is $v_0 = 0$. With these boundary conditions we check the effect of thermal springs placed inside the cavity, cavity dimensional, size of thermal springs (heat source) to reduce temperature. Convergence of the energy equation is $10^{-7}$. Convergence standard is temperature changes.

***Keywords—*** closed cavity, exothermic board, finite element, heat flux, natural convection

## I. INTRODUCTION

Heat transfer from the last few decades due to natural convection method considered high performance and many studies done and many papers are presented in this field. In 2002 natural convection of heat transfer inside a rectangular cube container walls that are part of it to produce heat in two-dimensional case review and to study the maximum in various paid Rayleigh number (1). In 2000 to study the flow field inside the rectangular container cube in the center of it a heat source is paid and stream lines in different pages has achieved. (2). In 1982 by moving into the chamber to the numerical method Bench mark to study and review the number of different Nu in Rayleigh number paid. (3). In 2009 Symbolic calculation for free convection for porous material with constant heat flux in a circular cavity (4). In 2008 Modelling of the temperature change in vertical ground heat exchangers (5). In 2007 experimental study of mixed convection laminar flow of water-Al2O3 nanofluid in horizontal tube with Uniform wall heat flux (6).This article examines the relationship between temperature changes with moving heat source and change its lengths, we have heat source on a rectangular cube face is vertical. at first heat source with constant heat flux and a certain size on the vertical side in seven different positions to review and put it explains temperature changes .then the thermal springs located in a specific location and length of the side will change the temperature check which is the maximum temperature obtain. Finally, change dimensions of the chamber maximum temperature on the heat source obtains.

## II. Problem Formulation

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \qquad (1)$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = \frac{-1}{\rho}\frac{\partial p}{\partial x} + \frac{\mu}{\rho}\nabla^2 u \quad (2)$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} = \frac{-1}{\rho}\frac{\partial p}{\partial y} + \frac{\mu}{\rho}\nabla^2 v \quad (3)$$

$$\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} = \frac{-1}{\rho}\frac{\partial p}{\partial z} + \frac{\mu}{\rho}\nabla^2 w - g\beta\Delta T \quad (4)$$

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z} = \alpha\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right) \quad (5)$$

### A. Non dimensional equations

$$\frac{\partial u^*}{\partial x^*} + \frac{\partial v^*}{\partial y^*} + \frac{\partial w^*}{\partial z^*} = 0 \qquad (6)$$

$$\frac{\partial u^*}{\partial t^*}+u^*\frac{\partial u^*}{\partial x^*}+v^*\frac{\partial u^*}{\partial y^*}+w^*\frac{\partial u^*}{\partial z^*}=-\frac{\partial p^*}{\partial x^*}+\left(\frac{pr}{Ra}\right)^{1/2}\nabla^2 u^* \quad (7)$$

$$v_0=0$$

$$\frac{\partial v^*}{\partial t^*}+u^*\frac{\partial v^*}{\partial x^*}+v^*\frac{\partial v^*}{\partial y^*}+w^*\frac{\partial v^*}{\partial z^*}=-\frac{\partial p^*}{\partial y^*}+\left(\frac{pr}{Ra}\right)^{1/2}\nabla^2 v^* \quad (8)$$

$$\frac{\partial w^*}{\partial t^*}+u^*\frac{\partial w^*}{\partial x^*}+v^*\frac{\partial w^*}{\partial y^*}+w^*\frac{\partial w^*}{\partial z^*}=-\frac{\partial p^*}{\partial z^*}+\left(\frac{pr}{Ra}\right)^{1/2}\nabla^2 w^*-1 \quad (9)$$

$$\frac{\partial \theta}{\partial t^*}+u^*\frac{\partial \theta}{\partial x^*}+v^*\frac{\partial \theta}{\partial y^*}+w^*\frac{\partial \theta}{\partial z^*}=\frac{1}{pr^{1/2}Ra^{1/2}}\nabla^2\theta \quad (10)$$

g=gravitational $\quad u, v, w$ =velocity component $m/s$

T=temperature $\quad$ β=coefficient of thermal expansion $1/k$

p=pressure $N/m^2$ $\quad \rho=$ fluid density, $kg/m^3$

$\mu$ =dynamic viscosity, $kg/m.s$ $\quad$ Ra=Rayleigh number

$v_0$=reference velocity $\quad$ α=fluid thermal diffusivity

Pr=prandtl number $\quad$ q=heat flux $\frac{w}{m^3}$

L,w,h= cavity dimensional $\quad$ L,W,H=heat source dimensional

H=heat source height $\quad T_\infty=$ temperature of environment

$$x^*=\frac{x}{H} \qquad u^*=\frac{u}{v_0} \qquad pr=\frac{\nu}{\alpha}$$

$$y^*=\frac{y}{H} \qquad v^*=\frac{v}{v_0} \qquad t^*=\frac{t}{H/v_0}$$

$$z^*=\frac{z}{H} \qquad w^*=\frac{w}{v_0} \qquad p^*=\frac{p}{\rho v_0}$$

$$v_0=\left(\frac{g\beta qH^2}{K}\right)^{1/2} \qquad Ra=\frac{g\beta qH^4}{K\nu\alpha}$$

$$\theta=\frac{T-T_\infty}{\frac{qH}{K}}$$

B. Boundary condition

u(0,y,z)=u( $L/H$ ,y,z)=u(x,0,z)=u(x,1,z)=u(x,y,0)=u(x,y, $W/H$ )=0

v(0,y,z)=v( $L/H$ ,y,z)=v(x,0,z)=v(x,1,z)=v(x,y,0)=v(x,y, $W/H$ )=0

w(0,y,z)=w( $L/H$ ,y,z)=w(x,0,z)=w(x,1,z)=w(x,y,0)=w(x,y, $W/H$ )=0

x=0 : $\theta$=0 , x= $l/H$ : $\theta$=0

y=0 : $\theta$=0 , y= $h/H$ : $\theta$=0

z=0 : $\theta$=0 , z= $w/H$ : $\theta$=0

x=0 , $L/H$ : $K\frac{\partial\theta}{\partial x}=q$

y=0, 1 : $K\frac{\partial\theta}{\partial y}=q$

z=0, $W/H$ : $K\frac{\partial\theta}{\partial z}=q$

III. Problem Solution

For this problem solving, we assume a cavity of $20\times 40\times 40$ cm and heat source dimensional $10\times 3\times 5$ cm, pr=0.7, Ra=$10^3$, the flow is Permanent, heat flux is constant. (fig1)

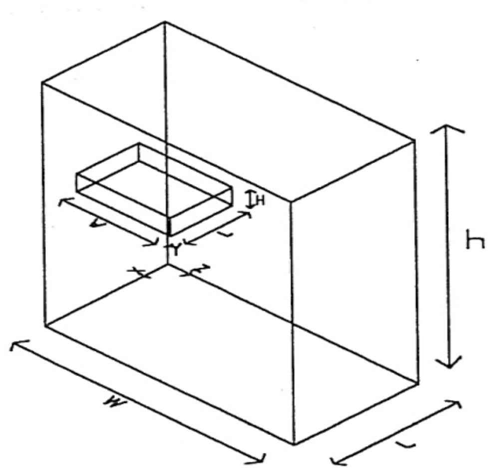
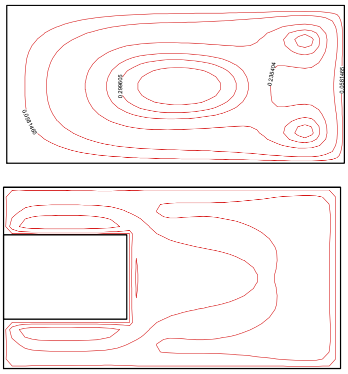


fig1: cubic cavity when one cubic heat source is on the vertical wall of cavity

At first we should check if the problem is correct or not, then solve it because enough scientific and experimental studies are not available. We compare the results with previous qualitative results which are available. For qualitative study we draw fluid flow in the planes xz, xy with different value for y and z when heat source is in the middle of vertical face symmetry completely. (Fig2)



**figa**

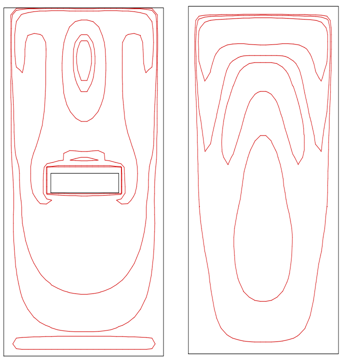


**fig (b)**

Fig2: stream lines are shown on planes x-y (fig a), x-z (fig b) when one heat source is in the middle of cavity's wall

Now, we must solve the problem. At first a heat source is on the vertical face of cavity (at y direction) and maximum temperature obtain with moving the heat source in seven location 5, 10, 15, 20, 25, 30 and 35cm from cavity froth . We see in fig(3) when heat source is near the cavity (5cm, 10cm, 30cm and 35cm), heat source temperature is the highest because the heat source is an obstacle in front of flow and the flow can't pass simply. Heat source temperature increases at the 20cm distance from cavity froth because heat source is far from the above and below walls and it can't lose heat .we change heat flux then we see the diagram is not changed; however the diagram is changed if the boundary condition is changed.

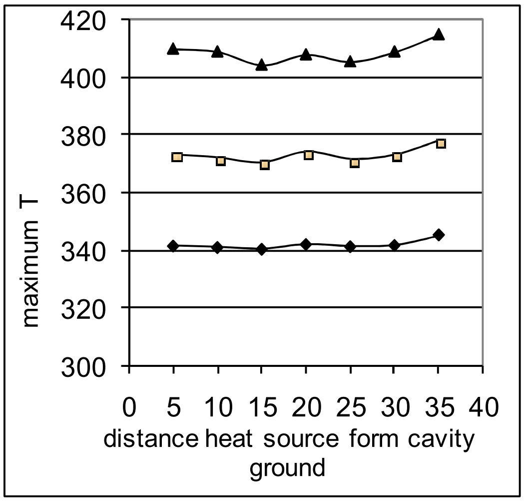



Fig3: maximum heat source temperature changes in correlation with distance between heat source and cavity ground in three heat fluxes

In Fig4 the temperature function has shown on the heat source which is in the center of wall. We can see that the maximum temperature occurred in the center of area and decrease at the edge of area because edges of heat source interchange heating with environment and then decrease temperature.

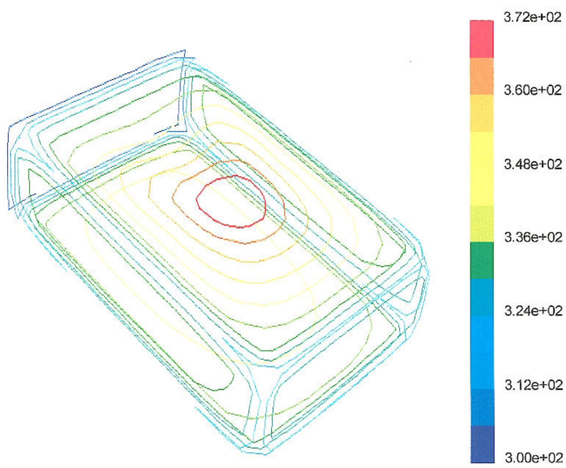



Fig4. This diagram show temperature changes in the heat source's wall in three directions

In fig5 temperature diagram at two different values of y has shown therefore at the length of heat source (z) temperature increase and then decrease.

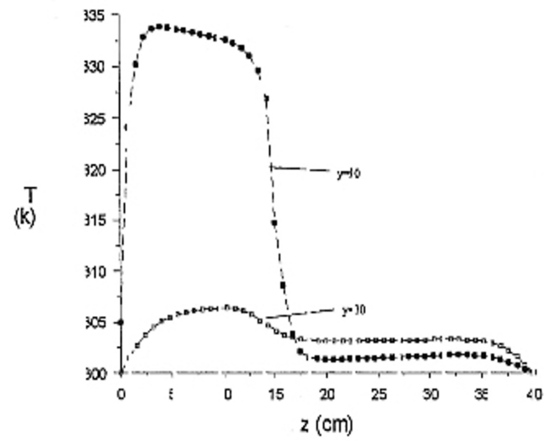
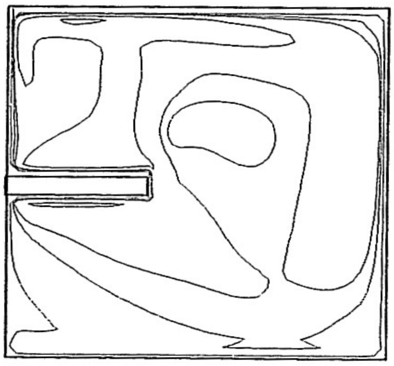
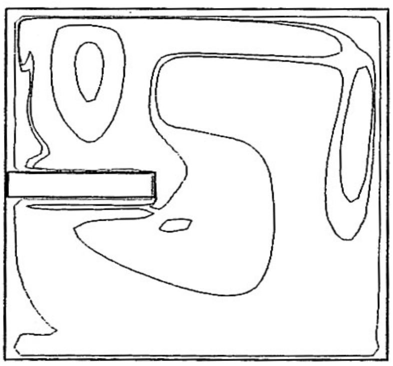



Fig5: heat source temperature ratio to the heat source's length with two different value of y

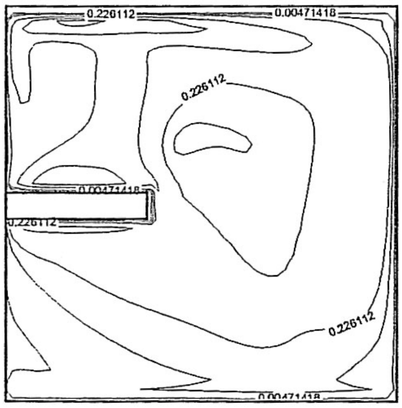
Fig6 ,fig7 and fig8 show stream-functions on the different planes of x, y, z when the heat source in the center of wall. We see that the most eddy occurred on the nearest pages to the heat source and eddy far from each other when the pages far from heat source. Fig 9 show stream –function on the plane of x in the cavity with three direction.



**X=5**

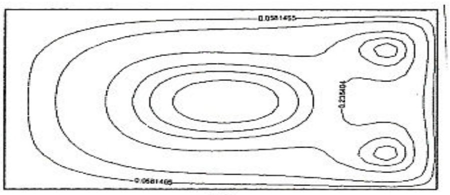


**X=10**

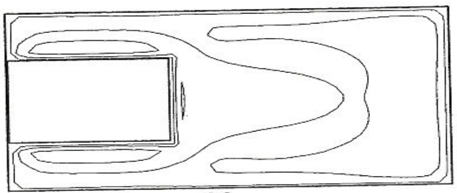



**X=15**

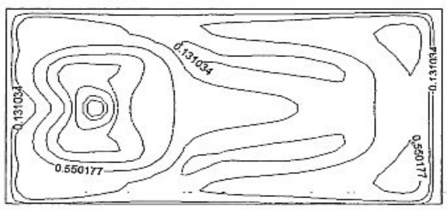
Fig6: stream-function is shown with three different values of x in the cavity



**y=10**



**y=20**




**y=25**

Fig7: stream-function is shown with three different values of y in the cavity

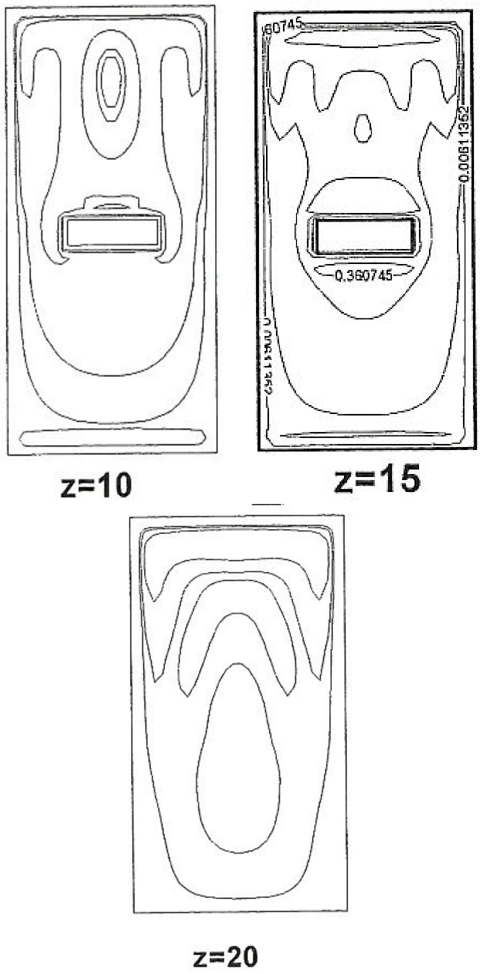



Fig8: stream-function is shown with three different values of z in the cavity

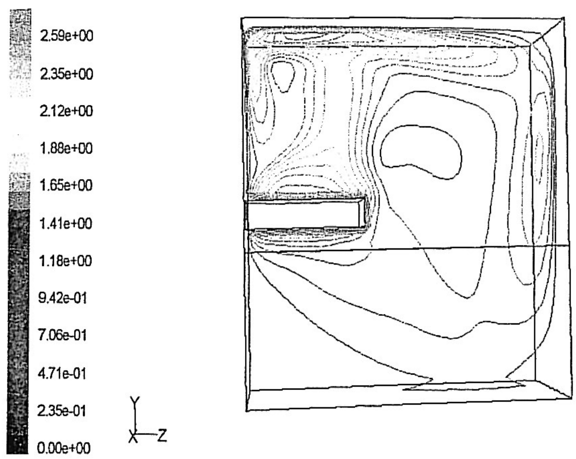



Fig9: stream –function on plane of x in three direction cavity

Fig 10, fig11 and fig12 show stream-function in three direction and we can see what place in the cavity is hottest than another place.

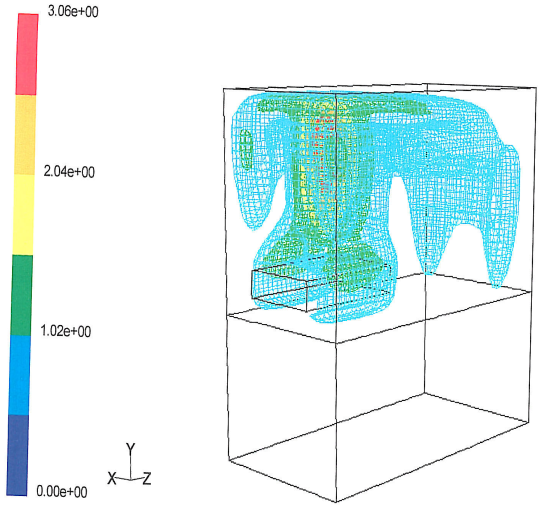



Fig10: stream-function in three direction l when heat source in the center of vertical wall

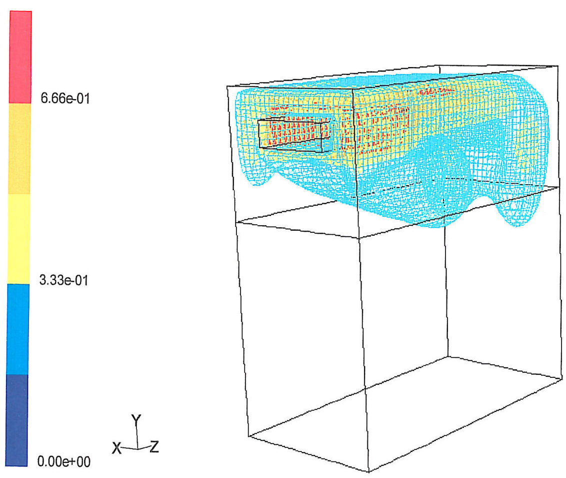



Fig11: : stream-function in three direction when heat source in the above of vertical wall

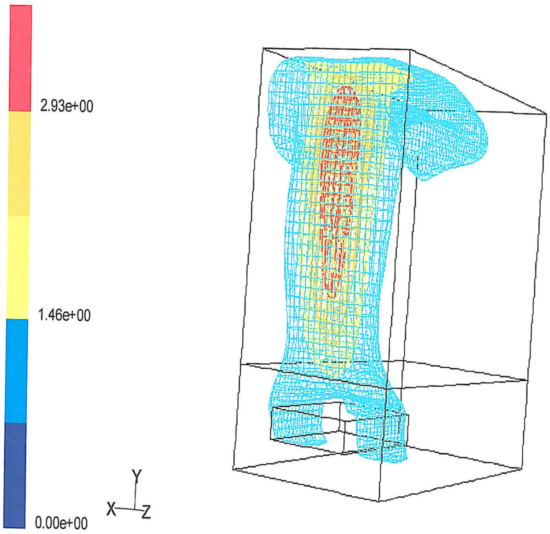



Fig12: stream-function in three direction when heat source in the below of vertical wall

In figure 13 we test another case. We put the heat source in the center of vertical wall and then change heat source dimension (change heat source length) therefore we examine various heat source lengths of 3, 5, 10, 15, 20, 25, and 30cm (seven cases).We can see in fig (13) that the heat source temperature is decreased until 25cm and after that increased because the area for heat transfer is big. In this image we can see diagram with three values for heat flux. All of them have the similar diagram. In figure 14 we can see stream-function in three direction .it show places that has maximum temperature.

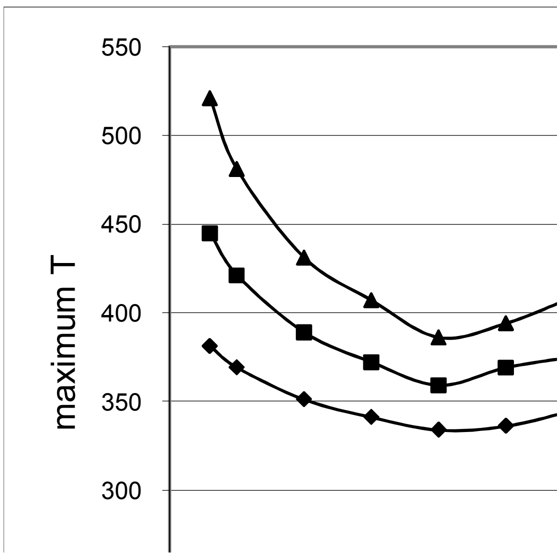



Fig13: maximum temperature changes in correlation with heat source's length when heat source is in the center of cavity's wall in three heat fluxes

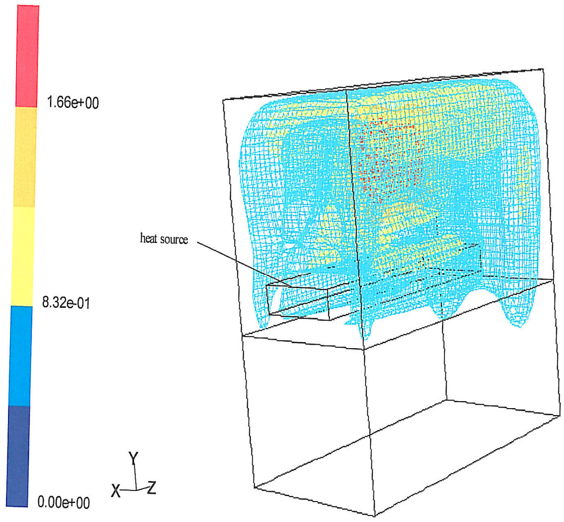



Fig 14: stream-function in three direction when heat source has maximum length and in the center of vertical wall

In fig (15) we can show values of temperature at the length of heat source .in this case the length of heat source is 40 cm . we see that temperature increase and then reduce but after that it increase suddenly and in 40cm it received to temperature of environment .we can see in this figure with two value of y and I obtain the same result.

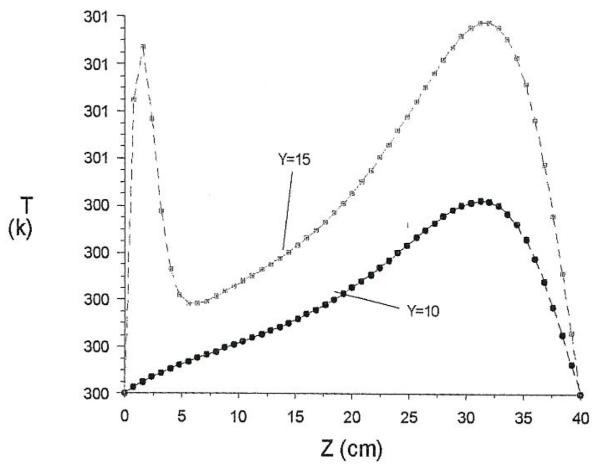



Fig15: Heat source temperature to the heat source's length in two different y when heat source has minimum length and in the center of cavity's wall

At the end we are decreased the high of cavity (we change $h/w$ ) however volume cavity is constant. With increasing height, temperature decreases because convection takes place simply but increasing height is limited because when h is increased then w is decreased therefore circulation flow takes place hard (fig16).in fig17 we can see stream-function in three direction when y/z=4 .it show maximum temperature where happen.

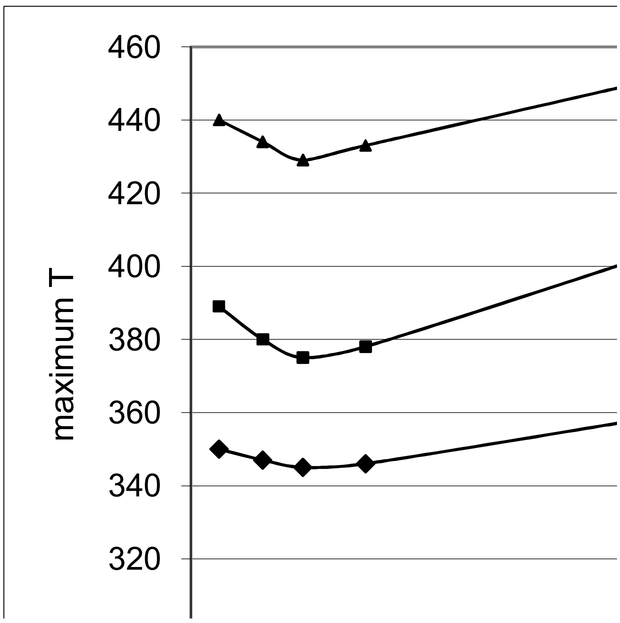



Fig16: Maximum heat source temperature changes in correlation with cavity dimension

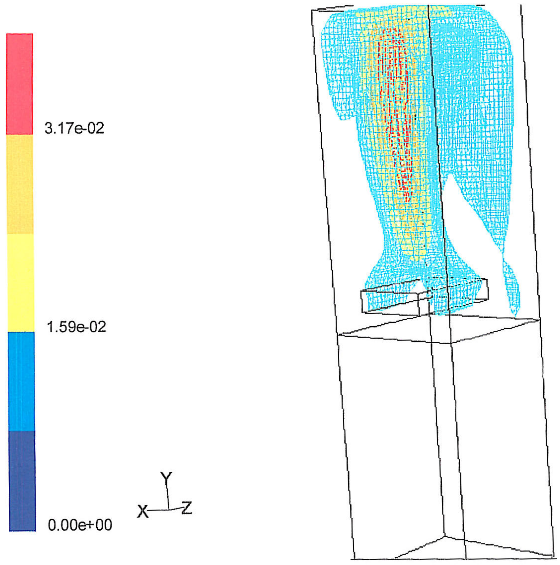



Fig17: stream-function in three direction when y/z=4

## IV. Conclusion

We result when we move heat source on the vertical wall of cavity minimum value of temperature happened when the heat source far from center of wall and near to above and below walls reduce heat source temperature because it can heat transfer with environment (wall's temperature is $T_{\infty}$).however heat source can't more near to the walls because temperature increased. In this problem heat source has minimum temperature in 15cm from ground .with changing cavity dimensional happen Minimum temperature when the heat source's length increased but it is limit. When $y/z = 1$ or $h/w = 1$ (cavity dimensional) heat source temperature is minimum. Therefore if we increased h (heat source's high), decreased temperature.

At the end we can result when length of heat source is 25cm, height of cavity is 40cm and heat source distance from ground is 15cm , is the best case that happened.

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