Distance Optimization and Numerical analysis of dual heating element in an enclosure on natural convection

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Abstract – **In a three dimensional rectangular enclosure the results of numerical investigation has been found on natural convection with heated parallel vertical plates located inside the enclosure.Simulation was performed by using commercial computational fluid dynamics package. The paper had been explored and discussed for the effect of spacing between the heated vertical plates and heat input on the flow also the heat transfer characteristics inside the enclosure.**

Index Terms – Enclosure, Volumetric heat generation, Modified Rayleigh number

I. INTRODUCTION

The specific features of natural convection such as low cost, reliability and ease of maintenance made its emergence as an effective method for cooling of electronic application devices. Over the last decade the role of natural convection in enclosures has gained significance in heat transfer literatures because of application in buildings, furnaces, cooling towers as well as electronic cooling systems. Experiment was performed by Horibe et al. [1] to investigate natural convection in an enclosure with horizontal parallel plates. The study varied the spacing between the parallel heaters and also heat flux to investigate the impact on the flow and heat transfer characteristics. They established the existence of two distinct flow characteristics viz vortex motion and flow along the heated surface. Anderson et al. [2] conducted experiments to study natural convection in triangular enclosures. The heat transfer coefficient calculated from the experiments were found to be agreed well and with that obtained from the correlation developed by Ridouane and Campo's, even though the correlation was applicable for lower Grashof numbers. Experimental study was conducted for Grashof numbers ranging 10^7 to 10^9. Kahveci [3] numerically investigated laminar natural convection in an enclosure divided by a partition with a finite thickness and conductivity. They used polynomial-based differential quadrature method for solving governing equations of flow and heat transfer. The results of their study shown that the presence of vertical partition in the enclosure has considerable influence in circulation intensity and there for the heat transfer characteristics across the enclosure. The study also shown that the thickness of partition has little effect on the average Nusselt number. Verol et al. [4] analyzed numerically natural convection heat transfer with a protruding heater located in triangular enclosure. The governing equations of flow and heat transfer formulated in terms of vorticity stream function and numerically were performed finite difference method. It was observed from the study location and height of the heater has a major impact on the flow and temperature field and heat transfer inside the enclosure. The study also shown that for better heat removal the ratio of height of the triangle to length of the bottom wall of the triangle must be higher and heater should be located at the centre of the bottom wall. Numerical investigation was performed by Alam et al. [5] study of natural convection rectangular wall with partial heating at lower half of left vertical wall and partial cooling at upper half of right vertical wall and rest walls are adiabatic. It was observed from the study that local heat transfer increased with increase in aspect ratio (height of the cavity to length of the cavity) and attains a maximum value at aspect ratio one.

The above literature survey reveals that both experimental and numerical investigation in natural convection in enclosure has been studied extensively by many researches. However natural convection in enclosures with heated parallel vertical plates has not been seen anywhere. The aim of the present work is numerically investigate flow and heat transfer in a rectangular enclosure with duel heat generating element.

II. METHODS AND MODELS

A model is made for the study and it is as shown in the figure. The enclosure of rectangular shape is selected and adiabatic condition is assumed except in left and right walls. The left and right walls of the enclosure are taken as aluminium. The distance between heat generating elements , denoted by S and height of the heater , denoted as L. The ratio between these two is known as aspect ratio.

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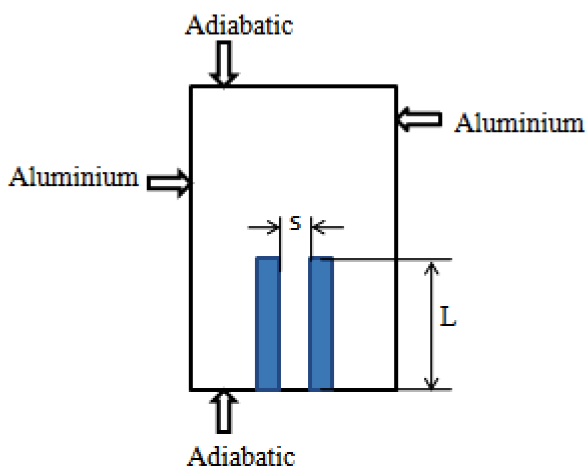

Fig.1 Schematic problem representation

The aspect ratio of range 0.2-0.8 is taken for the analysis. Also the nature of heat transre occuring during the variation of the heat input of 5W and 10W are evaluated. The left and right walls of the enclosure are assumed of constant temperature (room temperature). All other boundaries of the enclosure are assumed to be adiabatic.

III. METHODOLOGY

The determination of the effectiveness of heat transfer in an enclosures purely by natural convection is the main purpose of this study. For the analysis of the same a rectangular shaped enclosure similar to that dimensions having in real life applications has been selected. Inside the cabin two heat generating elements of thin rectangular plate shape are placed. The model of the above said setup is created and analysed in a commercially available computational fluid dynamic software namely ANSYS 14. For the purpose of analysis and simplicity the whole model is divided into solid zone and fluid zone. The heat generating elements and enclosure wall consists of the solid zone whereas the regions between them are selected as fluid zone. The objective of the analysis is to find out the optimum distance (S) between the two heat generating elements. Steady state heat transfer is assumed for the analysis. Also Boussinique approximation is taken for the study. The study is conducted for constant modified Rayleigh number but varying distance between heat generating elements for different aspect ratio.

IV. ASSUMPTIONS AND ANALYSIS

The following assumptions were made to simplify the problem, .

a) The solid and fluid zones are made to be material having constant thermal properties.
b) Here only the steady state heat transfer is considered.
c) Variations in air velocities are neglected.
d) Since the temperature difference is very small,so that Bossinesq approximation is considered.
e) According to the modified Rayleigh number the properties of air inside enclosure are varied.

V. GRID INDEPENDENCE STUDY

For optimizing the result of the simulation a grid independent study has been carried out. In this study the number of cells of a mesh are varied and then observed changes in the result. Here the variation in maximum temperature is observed.

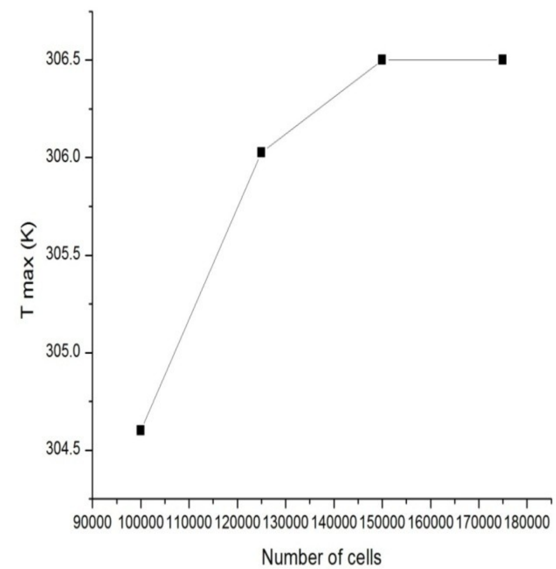

Fig.2Grid independent study

Figure shows the result of grid independent study. Here its clearly shown that after 150000 numbers of cells there is no considerable change in the maximum temperature.For reducing the computational load here its shown to select 150000 number of elements.

In this simulation work the different heat inputs are 5w and 10w. Results will be going to discuss with these heat inputs.

VI. SIMULATION PROCEDURE

A commercially available computational fluid dynamic software ANSYS 14 and its workbench is used for the creation

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of the model.The rectangular enclosure is modelled as hollow rectangular cabin (80mmx360mmx140mm) and heat generating element (8mmx100mmx40mm). The enclosure walls, heat generating elements and the region between them are categorised as solid and fluid zones respectively. The solid zone and fluid zone are treated as two different domains. The two domains are then discretized using unstructured hexahedral mesh. Maximum attention is given to maintain the orthogonal mesh quality as nearest to 1.

Analysis is carried out with simple algorithm and Presto for pressure discretization, second order upwind scheme for momentum and energy. Relaxation factors are taken to be default values. Convergence criterion set for $10^{-4}$for continuity, x-momentum and y-momentum and 10^{-4} for energy. Constant properties of air are considered. Natural convection is gravity based. Then, the energy equation is selected and the flow condition is taken as laminar. Different material properties, cell zone conditions and boundary conditions are applied properly for analysis. The calculation procedure is based on simple gradient type. Green gauss cell based pressure is selected as PESTO (since natural convection is selected). Momentum and energy is selected as second order upwind. The solution is initialized as standard and computed from all zones. Results and reports are generated for different aspect ratio.

Modified Rayleigh number

$$Ra = \frac{g\beta q''' L^5}{k\upsilon^2} * pr$$

RESULTS

Temperature Distribution

The study was carried out under specified conditions with varying aspect ratio and heat input. The temperature distribution was obtained for two different heat input, 5W and 10 W respectively. The aspect ratio in which the temperature distribution studied were 0.2, 0.4, 0.6 and 0.8.

Temperature distributions were studied along three lines parallel to the bottom of rectangular cabin. The three lines selected were one along the top of heat along with the heat generating elements, second along the middle and third at the bottom.

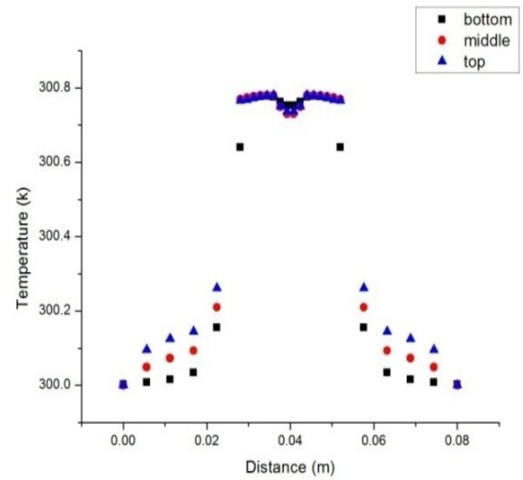

Fig.3. Temperature distribution for 5W, Aspect ratio 0.2

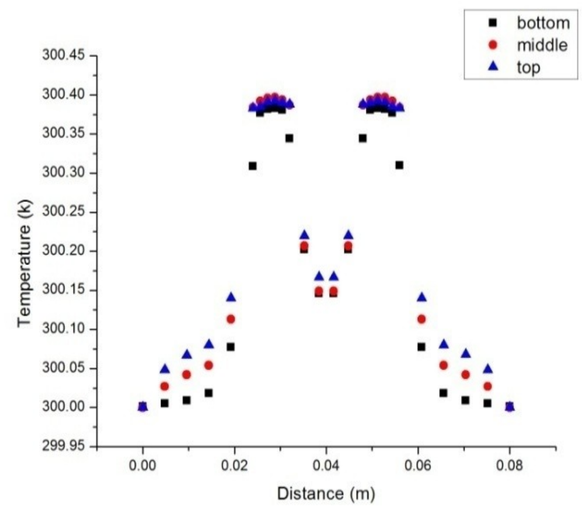

Fig.4. Temperature distribution for 5W, Aspect ratio 0.4

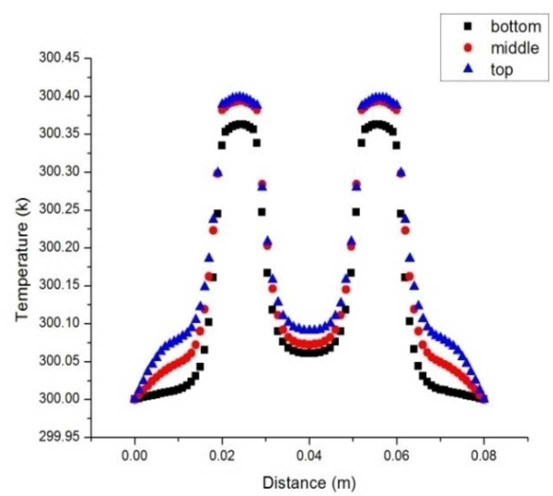

Fig.5. Temperature distribution for 5W, Aspect ratio 0.6

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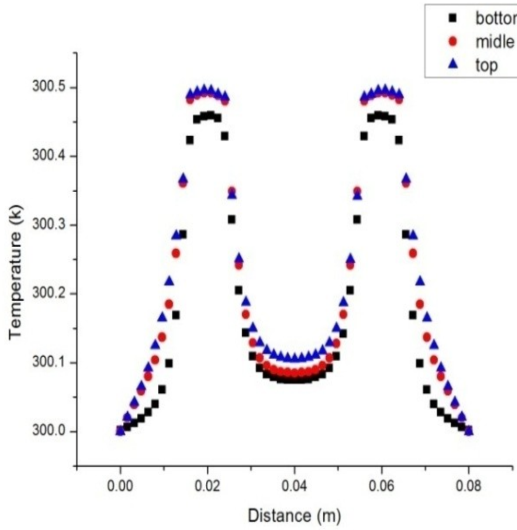

Fig.6. Temperature distribution for 5W, Aspect ratio 0.8

By observing temperature distribution for 0.2, 0.4, 0.6, 0.8 we can see that the maximum temperature attained for each aspect ratio decreases from aspect ratio 0.2 to 0.6 and it is again high for aspect ratio 0.8. The maximum temperature among the four aspect ratio is shown by that of 0.2, 300.5K. The lowest value of maximum temperature is obtained for aspect ratio 0.6.

The highest value of maximum temperature (T_{max}) obtained at aspect ratio 0.2 is due to the interaction of thermal boundary layer. The lowest value of T_{max} is obtained from aspect ratio 0.6 .

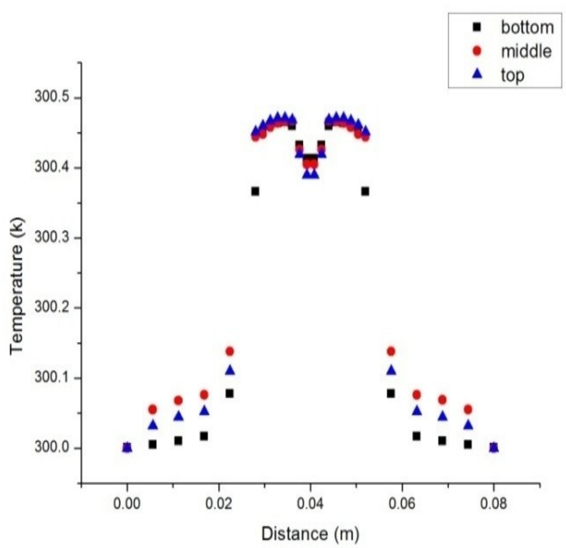

Fig.7. Temperature distribution for 10W, Aspect ratio 0.2

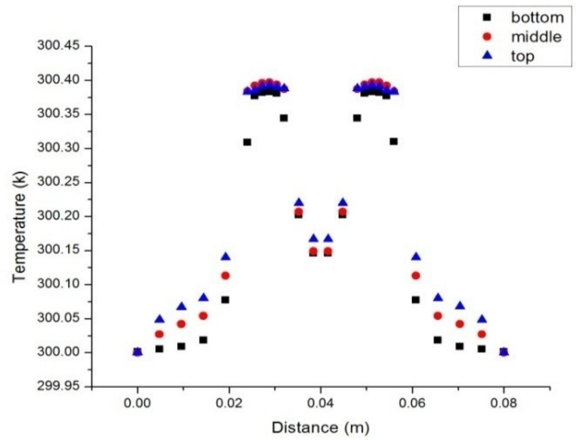

Fig.8. Temperature distribution for 10W, Aspect ratio 0.4

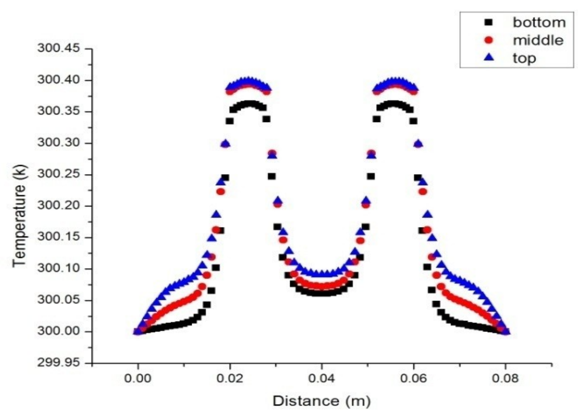

Fig.9. Temperature distribution for 10W, Aspect ratio 0.6

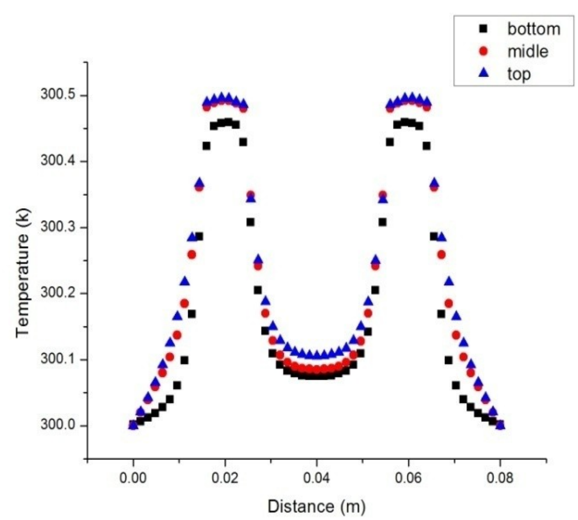

Fig.10..Temperature distribution for 10W, Aspect ratio 0.8

By observing heat input of 10w temperature distribution for 0.2, 0.4, 0.6, 0.8 we can see that the maximum temperature

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attained for each aspect ratio decreases from aspect ratio 0.2 to 0.6 and it is again high for aspect ratio 0.8 as same as the heat input of 5w . The maximum temperature among the four aspect ratio is shown by that of 0.2, 300.5K. The lowest value of maximum temperature is obtained for aspect ratio 0.6. The highest value of maximum temperature (T_{max}) obtained at aspect ratio 0.2 is due to the interaction of thermal boundary layer. The lowest value of T_{max} is obtained from aspect ratio 0.6 .

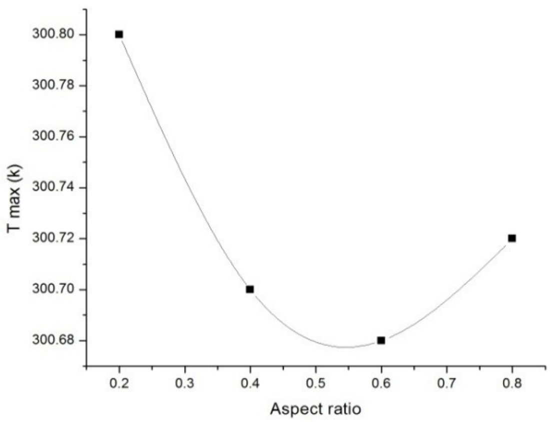

Fig.11. T max Vs aspect ratio for 5w

For more clarification of temperature distribution with aspect ratio two graphs are shown below, heat input of 5w and 10w respectively. From the graphs we can clearly seen that the maximum temperature is minimum in aspect ratio 0.6 in both 5w case and 10w case.

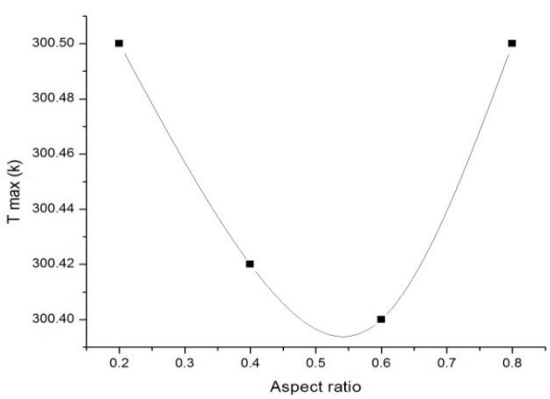

Fig.12. T max Vs aspect ratio for 10w

VII. CONCLUSION

Various aspect ratio has been used for the CFD analysis of natural convection. From the analysis following conclusions are made.

- Maximum temperature T_{max} is minimum for aspect ratio 0.6, because optimum spacing is 24mm.
- Average temperature spacing decreases with increase in the aspect ratio.
- The feature of symmetric flow of the fluid in the cavity is retained even in the presence of heating elements.
- Velocity vortex intensity is increased with increase in aspect ratio.

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