Numerical Investigation of Natural Convection of Differently Heated Two Dimensional Vertical Plates

Vishwanth[1] Sudhir Singh Rajput[2]
[1]PG Research Scholar [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]RITEE, Raipur, India

Abstract— In this research work natural convection in two dimensional vertical cavity is studied numerically for differently heated air filled rectangular cavity. Vertical cavity with two adiabatic and two hot and cold wall with different aspect ratio of 1,2,4 and 8 has taken for investigation. The plate inclination angle was fixed at 00 means only vertical plate has taken for investigation. Natrually the heat transfer was investigated over the wide range of Rayleigh number from 103 to 106 .Air is the fluid media in between the closure wall and a correlation of average Nussalt number are proposed for vertical cases of rectangular enclosure. Solutions are obtained for several Rayleigh numbers with Prandtl number Pr = 0.70 and aspect ratio 1,2,4 and 8.The Pressure-Velocity Coupling Method used with Non-Iterative Time Advancement scheme used to solve the problem. The distribution of thermal and stream function are taken as a function of thermal and geometrical output parameter for given problem. Two stage investigations have been performed to find out the variation in the result between different approaches.

Keywords: CFD- Computational Fluid Dynamics, FEM- finit element method, Nu- Nusselt number, AR- aspect ratio, Rayleigh number

I. INTRODUCTION

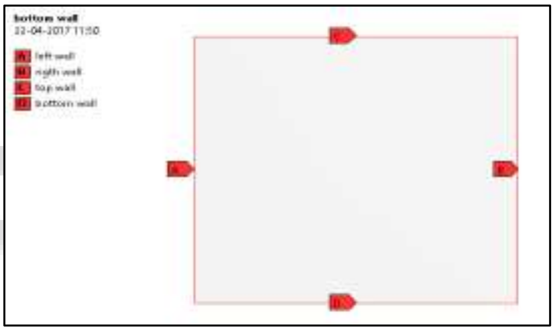
The natural convection flow and heat transfer in rectangular enclosures are extensively Studied due to its diverse applications. In the vertical position enclosures can acts as insulation for doors and windows of buildings, air conditioning compartment of trains, industrial furnaces, chimney and many heat transfer equipment's and in an inclined position it is used in skylights, roof windows, solar collector storage and many other solar applications. The present study is concern with natural convection heat transfer in vertical enclosures. The vertical enclosures consist of two glass panels set in a frame and separated by a small space. The gap between the glass panels is filled with air since air acts as insulator and air being a transparent medium allows light to pass through it.Convection is transfer mode is comprised of two mechanisms. In addition to energy transfer by random molecular motion (diffusion), energy is also transferred by the bulk of macroscopic motion of fluid. The fluid motion is associated with the fact that at any instant large number of molecules are moving collectively. Such motion, in presence of a temperature gradient, contributes to heat transfer. The heat transfer by convection is given by Newton's law of cooling:-

$$Q = h\,A\,(Ts-Tf)$$

In CFD approaches, the partial differential equations are converted into algebraic equations by discretization methods (i.e. finite difference, finite volume and finite element method). The algebraic equations are modified to incorporate boundary conditions. The large set of algebraic equations so obtained, is then solved by iterative numerical procedures to obtain theUnknown flow variables like pressure, velocity, temperature etc. at all grid points in the domain of interest. The solution can then be visualized in the form of velocity vector plot, contour plots of pressure, temperature or any other derived quantity. Important engineering quantities like heat flux, drag force, lift force; pressure drop etc. can be calculated from the solution.

II. BOUNDARY CONDITION

The present study deals with two-dimensional natural convection taking place inside enclosed Space. The enclosed cavity has differentially heated side walls and adiabatic top and bottom wall. In this problem the cavity is filled with air and the effect of conduction and radiation is neglected. The space between the enclosures is filled with air since air being transparent allows light rays to pass through it and also acts as insulator.



A. *Schematic representation of vertical cavity*

The scope of the present study is to employ CFD methodology for computing laminar natural Convection flow and heat transfer in two-dimensional vertical air cavities. The dimensionless Parameter i.e. Nusselt number depends upon Rayleigh number, Aspect ratio, Inclination and Prandtl number. In the present study the Prandtl number and inclination are fixed in all the cases so the Nusselt number is the function of Rayleigh number and Aspect ratios. In the present study the Nusselt number is computed for the range of Rayleigh number and Aspect ratios is varyfrom 1 to 8 as 1,2,4& 8.

III. METHODOLOGY

The creation of geometry in ansys software is based on hierarchical order. It means that first Coordinates of the geometry are created and then curves are drawn through coordinates andfinally face is created bounded by those curves. The face forms the computational domain. Similarly the geometry of other aspect ratio and Rayleigh no has been created in the same plate form and different dimension.The geometry of the enclosed space, meshing and boundary identification is carried out in Ansys software. The dimensions of the cavity are permit to cover wide range of Rayleigh number (103 ≤ Ra ≤ 106) and aspect ratio (1≤A ≥8).

IV. MESH GENERATION

After creating the geometry it is required to divide the control volume into smaller number of Nodes and element of finite size, therefore it is called finite volume method. The method of splitting the Control volume into small finite size volume is known as meshing of the controlvolume. As Geometry is simple structured grid is preferred as it gives better results as compared to unstructured grid. Here we were using the minimum size of node 1e-04 m for mesh generation of square cavity.

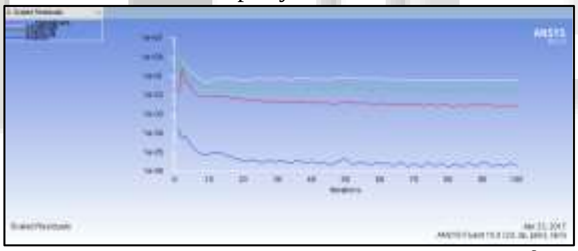
V. PROPERTIES OF FLUID

The properties of fluid are obtained at a mean temperature of differentially heated side walls,

Which is kept at temperature of 30^{0}C and 35^{0}C. The properties of air are calculated at 32.5^{0}C.

PROPERTY	UNIT	METHOD	VALUES
Temperature	K	Constant	305.5
Density	Kg/M3	Boussinesq	1.15575
Specific heat	J/kgK	Constant	1005
Thermal conductivity	W/mk	Constant	0.02634
Viscosity	Kg/ms	Constant	1.87E-05
Thermal expansion	1/K	Constant	0.003273
Gravitational acceleration	m/s2	Constant	9.801
Dynamic viscosity	Kg/ms	Constant	0.00002074
Beta	1/k	Constant	2.87E-03

Property of fluid



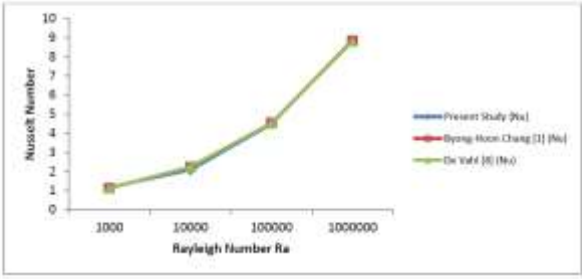
Convergence window of enclosure at Ra = 10^6

VI. RESULT & DISCUSSION

In order to validate the code two-dimensional, laminar, steady natural convection of air with differentially heated side walls and adiabatic top and bottom walls of square cavity was solved. The thermal conditions and dimensions of the enclosures are permit to cover wide range of Rayleigh number varying from $10^3$to 10^6. The temperature difference between side walls was kept at constant for all the cases. The property of air is obtained at mean temperature of hot wall and cold wall. The computed results of heat transfer for average Nusselt number are obtained by using commercial Computational Fluid Dynamics software and compared with results available in the literature[1].

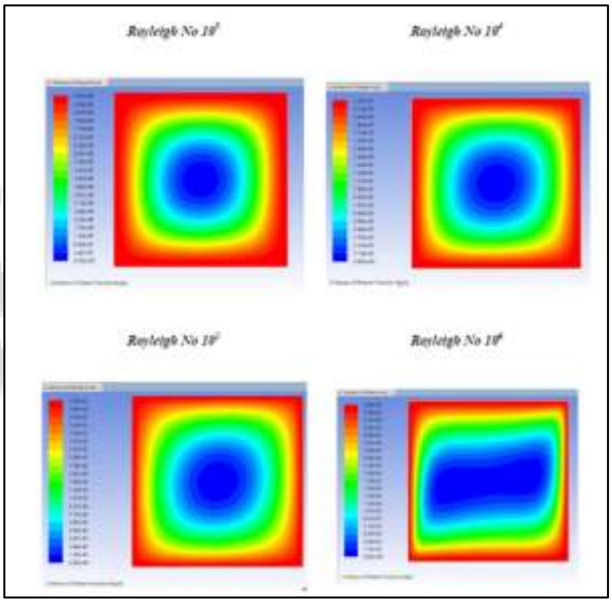
A. *Validation of results for square enclosure*

S No	*Rayleigh Number Ra*	*Present Study (Nu)*	*Byong-Hoon Chang [1] (Nu)*	*De Vahl [8] (Nu)*
1	10^3	1.18	1.118	1.118
2	10^4	2.18	2.241	2.243
3	10^5	4.42	4.532	4.519
4	10^6	8.77	8.848	8.799



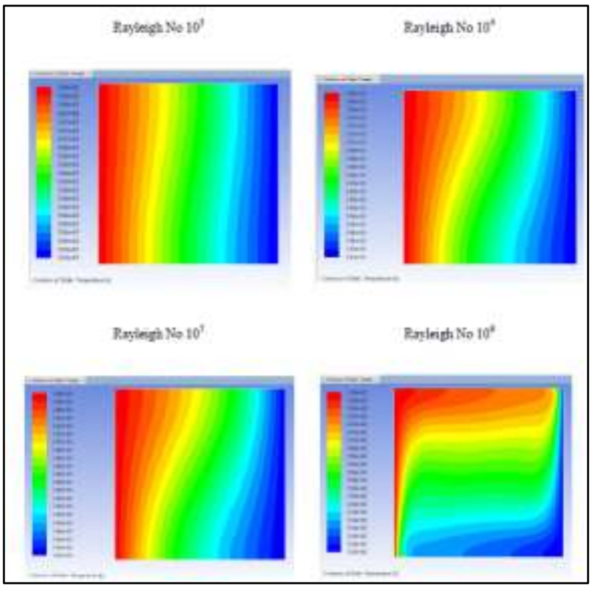
Validation of Nusseltno. at different Rayleigh number

The stream function plot is use to visualize the flow of air in square cavity for different Rayleigh number varying from $10^3$to 10^6shown below.



Stream function plot for square cavity at different Rayleigh number

The temperature contour plots is used to study temperature distribution of air in square enclosures for different Rayleigh number varying from 103 to 106 shown in the fig.5.4 the detail study of temperature contour its is found that the path of contour becomes irregular with increasing the Rayleigh No.



Temperature contour plot for square cavity at different Rayleigh no.

VII. CONCLUSION

The important conclusion can be summarized as follows:-

- The Nussalt Number is directly proportional to the Rayleigh Number.
- The stream function plot is circular for aspect ration 1 and 2 and it goes deformed for higher aspect ratio and Rayleigh Number.
- The temperature distribution of air inside enclosed spaces is obtained with the help of temperature contours.
- The present results of heat transfer for two-dimensional, laminar, steady natural convection flow is obtained by using Computational Fluid Dynamics Software and compared with the results of Byong-Hoon Chang. The present results show very good agreement with results of Byong-Hoon Chang.
- Based on computational results of Nusselt number obtained by Computational Fluid Dynamics software, the correlations of heat transfer is proposed using least square curve fitting.

REFERENCES

[1] Chang B.H. "Numerical Study of Flow and Heat Transfer in Differentially heated enclosures" International journal of Thermal Science, 18, 451-463, 2014.

[2] Corcione, M., "Effects of the Thermal Boundary Conditions at the Sidewalls upon Natural Convection in Rectangular Enclosures Heated from Below and Cooled from Above", *International Journal of Thermal Sciences*, *42*, 199-208, 2003.

[3] Elsherbiny S.M., Raithby G.D., Hollands K.G.T., "Heat transfer by natural convection across vertical and inclined air layers", Journal of heat transfer, 1982, 104, 96-102.

