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CFD Analysis of Natural Convection Flow through Inclined Enclosure

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ABSTRACT : *The Natural convective laminar flow of two dimensional inclined rectangular enclosures is investigated by computational fluid dynamic analysis (fluent) in ansys.The upper and right wall keep adiabatic and other two walls are held in at different temperatures. The Rayleigh No varies from 10^3 to 10^6 to study the natural convection. The effect of inclination angle of the square and rectangle cavity on natural convection flow is studied for each combination of Rayleigh No. The effect of stream function and temperature contour show similar properties at low Rayleigh No. and it goes increases and show different pattern at high Rayleigh No.*

Keywords: *CFD (Computational fluid dynamics), Ra (Rayleigh Number).*

I. INTRODUCTION

In the last few decades, natural convection has been the interest of many researchers. Various geometries of fluid-filled rectangular vertical and horizontal enclosures have been theoretically and experimentally modeled in order to find out the effects of some design parameters on the thermal performance of simulated systems. The natural convection flow and heat transfer in rectangular enclosures are broadly Studied due to its various applications. In the vertical position, enclosures can acts as insulation for doors and windows of buildings, air conditioning compartment of trains, industrial furnace, chimney and many heat transfer equipments 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. The 2-D representation of vertical enclosures is shown in the figure.

II. PROBLEM FORMULATION

The present study deals with two-dimensional natural convection taking place inside inclined enclosed Space. The enclosed cavity has differentially heated left and bottom walls and adiabatic top and right walls. 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.

Assumptions

The following assumptions are made in the present work:

1. Flow is steady laminar natural convection.
2. Flow is two -dimensional.
3. The fluid properties are constant except that the variation of density with temperature is accounted for in the formulation of buoyancy term (Boussinesq approximation).
4. The effect of conduction and radiation effects are neglected.

Range of Parameters Investigated

Rayleigh number = 10^3,10^4, 10^5, 10^6,
Aspect ratio A = 1,2 & 4
Inclination Ø = 0^0 to 90^0 with 30°, 45° 60° and 90°
Prandtl number (Pr) = 0.7

III. METHODOLOGY

Geometry: In order to create the geometry of the inclined enclosure square cavity we are using the Ansys fluent work bench. First of all we had created the separate module for CFD and then in geometry tool create the two dimensional square surface according to the Rayleigh No.10^3.The inclination angle vary from 0 to 90^0. The analysis has been performed for each Rayleigh No varied from 10^3 to 10^6.

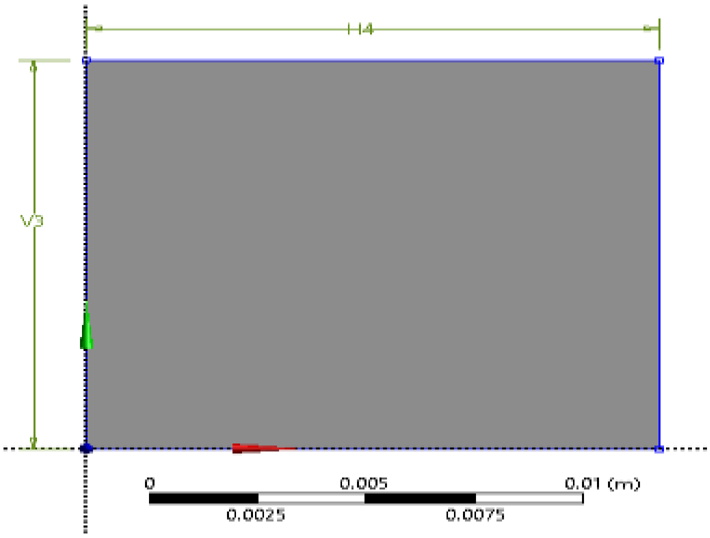

Figure1. Surface of Square cavity

Meshing of geometry

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 control volume. 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.

Table 1: Boundary condition of inclined enclosure

BOUNDARY	TYPE	VALUES
Left Side wall	Isothermal	T=305 K
Bottom wall	Isothermal	T=300 K
Top wall	Adiabatic	q= 0 W/m2
Right wall	Adiabatic	q= 0 W/m2

Solution method

In order to solve the given boundary condition in ansys fluent workbench we were using the Pressure-Velocity Coupling Method. ANSYS Fluent provides four segregated types of algorithms: SIMPLE, SIMPLEC, PISO, and (for time-dependant flows using the Non-Iterative Time Advancement option (NITA) Fractional Step (FSM). These schemes are referred to as the pressure-based segregated algorithm. Steady-state calculations will generally use SIMPLE or SIMPLEC, while PISO is recommended for transient calculations. PISO may also be useful for steady-state and transient calculations on highly skewed meshes. In ANSYS Fluent, using the Coupled algorithm enables full pressure-velocity coupling, hence it is referred to as the pressure-based coupled algorithm.

IV. RESULTS & DISCUSSION

The result obtained from the analysis of inclined enclosure is critically analyzed in four different phases. In all different phases same boundary condition were applied and results obtained by the CFD analysis are compared with analytical result of B H Chang. In first phase we compare the result obtained by the CFD analysis of square cavity in vertical position at 0^0 angles while in second phase we analyze the square enclosure with different angle and in final phase compare the result of analytical and CFD analysis of rectangular enclosure with aspect ratio 1, 2 and 4 with different inclination.

A) Validation of Present Results of horizontal square enclosure.

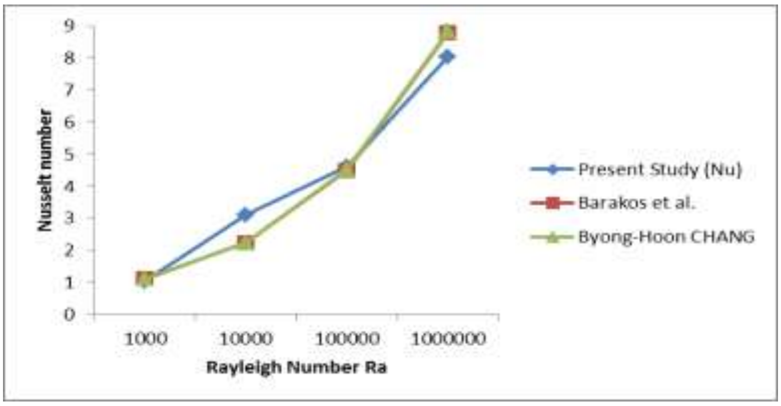

Fig. 2 Validation of Nu for square enclosure at different Rayleigh number

B) Validation of Present Results of inclined enclosure at Aspect Ratio 1

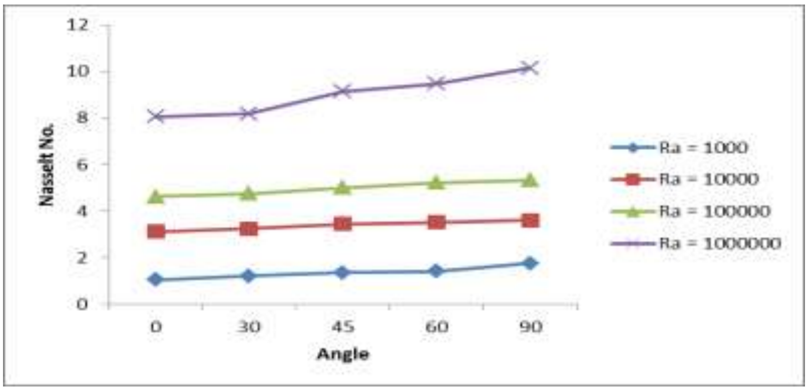

Fig.3 Nusselt number plot for inclined cavity at AR 1

C) CFD Results of inclined Rectangle enclosure with aspect ratio 2

The difference in the average Nusselt number between 10^3 to 10^6 for AR = 2 was about 87.5%, As the angle was increased from 0° to 90^0 the lower cell starts to elongated and its size also increases with inclination angle as per Figure 3 shows that heat transfer is the lowest at this inclination angle of 30°.

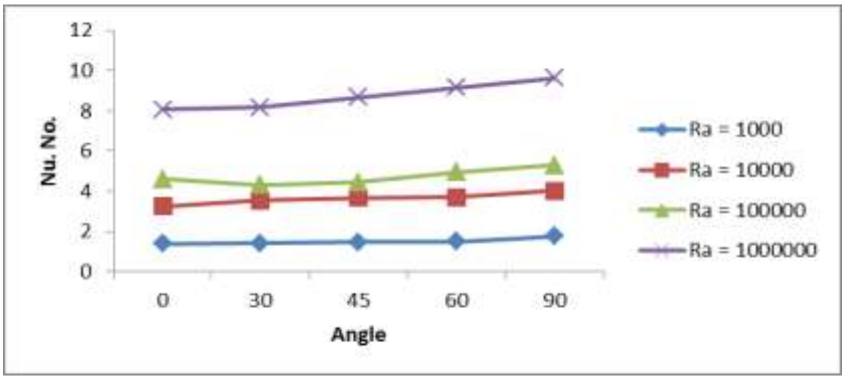

Fig. 4: Distributions of Nusselt Number for Rectangular Cavity at Aspect Ratio 2

D) CFD Results of inclined Rectangle enclosure with aspect ratio 4.

The Phase IV concern with the heat convection of rectangle enclosure with aspect ratio 4 at the lower Rayleigh number the size of round cell increase with the angle but in case of higher Rayleigh number its behavior is unpredictable it create two or more ring and at 0° and 30 ° but in case of higher inclination it create only one ring at the center.

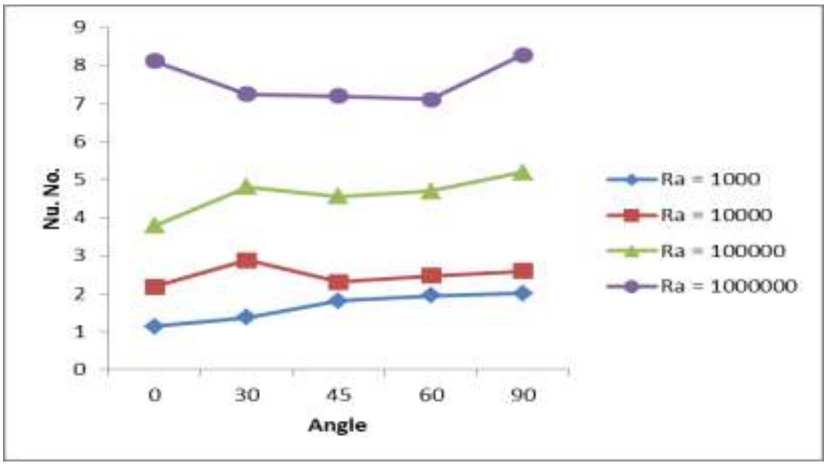

Fig. 5: Distributions of Nusselt Number for Rectangular Cavity at Aspect Ratio 4

V. CONCLUSIONS

The Important Conclusion Can Be Summarized As Follows:-

- It is observed that the Nusselt number increases with increase in Rayleigh number.
- It is observed from stream function plot that for low Rayleigh number, circulation pattern exist and number of circulation cells increase with an increase in 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 Mr B H Chang [1].

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