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I hereby declare that I have read this report and from my point of view this report is sufficient in term of scope and quality for purpose for the award of Bachelor of Degree in Mechanical Engineering (Thermal-Fluid)

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NATURAL CONVECTIVE HEAT TRANSFER IN SQUARE ENCLOSURE WITH PARTITION ON TOP WALL

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This report presented to fulfill the requirement in term to obtain Bachelor of Degree in Mechanical Engineering (Thermal-Fluid)

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DECLARATION

"I admit this report has been written by me myself except for some quotation that has been noted well for each of them"

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DEDICATION

This report is dedicated to my beloved parents,
Baba Noor bin Baba Ahmad and Noraziah binti Baba Noor.

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Thanks to Allah s.w.t. upon the completion of this report. Not forgetting my parents who always support me no matter what obstacles came through. Also special thanks to my supervisor, Mr. Mohd Irwan bin Mohd Azmi in guiding me along this report writing and project completion.

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ABSTRACT

This project is about studies on natural convection in square enclosure with partition on top wall. Two dimensional numerical solution for the square cavity were compared with the experimental result that has been done by other researcher. Boussinesq approximation had been considered as the natural convection involve with presence of gravity effect. The Rayleigh number for the cases is 1×10^7 as the result by the previous researcher. The model was a square cavity with double partition on top wall. The three different effects that were studied are the effects of different partition location, different partition lengths and different number of partition. For each case, the streamlines and isothermal lines was visualized and compared. Parameter for the different condition is same as the experimental data by the previous researcher. The result for different partition location shows that distance of partition that further from vertical wall produces more air circulation but most of the region in the square enclosure was filled with hot temperature. For the effect of different partition length, short length of partition shows better distribution of temperature in the cavity and more sufficient air circulation. Different number of partition shows well distributed temperature and sufficient air circulation on having double partitions. For a better air circulation enhancement, it is better to have double partition in short length of partition that is located in the middle of the top wall to optimize air circulation and temperature distribution.

ABSTRAK

Projek ini bertujuan untuk mengkaji perolakan semulajadi di dalam ruangan segi empat sama dengan sekatan di atas dinding. Penyelesaian berangka dua dimensi untuk ruangan segi empat sama akan dibandingkan dengan keputusan eksperimen yang telah dijalankan oleh pengkaji yang lain. Penaksiran Boussinesq telah diambil kira apabila terdapat penglibatan tarikan graviti pada perolakan semulajadi. Nombor Rayleigh untuk kes ini adalah 1×10^7 seperti keputusan yang telah diperoleh dari pengkaji yang terdahulu. Model itu dijangkakan untuk keadaan yang berbeza dengan kehadiran dua sekatan di atas dinding. Tiga kesan berbeza telah dikaji iaitu kesan perbezaan lokasi sekatan, perbezaan panjang sekatan dan perbezaan bilangan sekatan itu divisualisasikan dalam bentuk garisan arus dan garisan suhu tetap. Parameter untuk keadaan yang berbeza adalah sama seperti maklumat eksperimen dari pengkaji terdahulu. Keputusan untuk perbezaan lokasi sekatan menunjukkan bahawa sekatan yang berada jauh daripada dinding tegak menghasilkan peredaran udara yang lebih tetapi kebanyakan kawasan di dalam ruangan segi empat sama diisi dengan suhu panas. Untuk kesan terhadap perbezaan kepanjangan sekatan, sekatan yang pendek menunjukkan suhu yang dibahagikan sama rata di dalam ruangan dan peredaran udara yang mencukupi. Bilangan sekatan yang berbeza menunjukkan pembahagian sama rata untuk suhu dan peredaran udara yang mencukupi apabila mempunyai dua sekatan. Untuk penambahbaikan peredaran udara, adalah baik untuk mempunyai dua sekatan yang pendek dan terletak di tengah-tengah dinding atas untuk mengoptimumkan peredaran udara dan pembahagian suhu

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LIST OF SYMBOL

C	=	Constant in the Nusselt-Rayleigh number correlation, $Nu=C.Ra^n$
C_p	=	Specific heat *(J/kg.K)*
g	=	gravitational acceleration (m/s^2)
G_r	=	Grashof number
k	=	Conductivity *(W/ mK)*
n	=	Index in the Nusselt-Rayleigh number correlation, $Nu=C.Ra^n$
Nu	=	Nusselt number
P	=	Dimensionless pressure
Pr	=	Pandtl Number
q	=	Heat transfer per unit area (W/m^2)
Ra	=	Rayleigh number
T	=	Temperature *(K)*
T_B	=	Bottom temperature *(K)*
T_c	=	Cool temperature *(K)*
T_H	=	Hot temperature *(K)*
T_T	=	Top temperature *(K)*
u	=	Velocity component in x-axis
v	=	Velocity component in y-axis
ν	=	Kinematic viscosity
y	=	Coordinate direction
β	=	Volumetric thermal expansion coefficient (K^{-1})
θ	=	Dimensionless temperature
θ_T	=	Dimensionless temperature at top wall
μ	=	Dynamic viscos*ity*
ρ	=	Density (kg/ m^3)

ϕ	=	Dimensionless temperature
Ψ	=	Dimensionless stream function
ψ	=	Stream function
Ω	=	Dimensionless vorticity
ω	=	Vorticity

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CHAPTER I

INTRODUCTION

1.0 BACKGROUND

Due to several application of natural convection in cavities such as heating and ventilating of living space, energy transfer in solar collectors and electronic packaging; it is important to study the phenomena of natural convection in cavity (Wu *et al*, 2009). As there are temperatures different in a medium, transition of thermal energy will occur. This phenomenon is called heat transfer (Incropera *et al*, 2007). Three modes that involves in heat transfer are conduction, convection and radiation modes.

Difference between temperature of surface and fluid is the result of energy transfer from a surface to a fluid flowing process which is a definition of heat transfer convection. Convective heat transfer can be divided into force convection, natural convection and mixed convection. Natural convection or known as free convection is a result of flow which is not affected by any external force. It occurs due to the temperature gradient where the flow is initiated by the body itself which is medium such as air.

In order to identify fluid flow characteristic of natural convection, numerical solution is one of the method that can be used. Other methods that also can be used are experimental and analytical solution. Numerical solution is a method that used to solve

mathematical problem as the analytical method may not overcome the difficulty of the problem.

1.1 NUMERICAL METHOD

In solving problem, there are several method that can be used which is experimental, analytical and numerical solution. Experimental solution which is also known as empirical solution is a direct approach where the answer is obtained from experiment and knowledge applied on variation behavior (Patil *et al,* 2009). While for analytical solution, expression of interdependent variable is used in order to solve the problem by applying modified equation.

Generally, the term 'numerical method' can be defined as an alternative when analytical technique cannot be used to solve mathematical model (Amos *et al*, 2008). Using numerical method, the solution will be an approximate numerical value of answer. Even though the value is approximate, by execute an iterative manner; the answer can be accurate as it is desired (Gilat *et al*, 2008).

Numerical method is widely use such as in engineering and medical field. For example, it can be used to solve problem regarding fluid flow characteristic which is in engineering field and flow of blood inside human body.

1.2 ADVANTAGES OF NUMERICAL METHOD

There are several reasons where numerical solution can become a better solution compared to experimental and analytical solution. Due to these reason, numerical solution is used after both solution that had been mention as in 1.1 Numerical Method.

As the solving mathematical problem become more complex and difficult to be solved, approximation in numerical solution can be a better way. This is because of

numerical solution is using different values of independent variable compare to analytical solution that using expression of independent variable as technique to provide solution (Patil *et al*, 2009).

While for experimental or empirical solution, using numerical solution is lower in cost in term of research. This is because of numerical method is only using simulation as a medium to run the program to solve the problem but experimental solution need to used apparatus which is need to set up and if the result is not as desired, the experiment will be set up again. Not only it consumes a lot of cost, experiment also need more time especially when the test run need to be repeated.

In addition, using numerical method can clearly show the result. For example in fluid flow problem, the flow pattern of the fluid can be seen directly from the isothermal line and streamline. Besides, parameter of the subject tested can be changed instantly and the result also changes at the same time. This is show that there is no need a lot of time as the result can be obtained after the parameter change compare to experimental solution that need to be set up the apparatus as the parameter need to be changed.

1.3 DISADVANTAGES OF NUMERICAL METHOD

Although numerical method give benefit as it is being compare to analytical and experimental solution, numerical solution still has weakness. There are some point which is making numerical method is the other choice instead of using analytical and experimental solution as a main solution.

As all known, numerical method is an approximation approach in order to solve mathematical problem. This show that the value desired is only in approximation and not the exact value compare to using analytical and experimental solution. Besides, in order to get an accurate value using numerical solution, lots of iteration need to be done which is will consume more time to solve the problem accurately in value desired.

To solve mathematical using the numerical solution, lots of time is needed as designing the coding to program the numerical solution if error may occur during programming. Deep understanding is important in order to achieve a right coding programming to solve the mathematical problem.

1.4 PROBLEM STATEMENT

Natural convection is initiated by temperature difference which affects the density and relative buoyancy of a fluid. This phenomenon occurs without the assistance of any external force. Natural convection in a square enclosure problem is often used as a benchmark for numerical solutions. It is important to assess the capability of a numerical model to produce results. In this study, the capability of the numerical method available shall be assessed with existence of partition on top wall. The validated model will then be used to predict results at different condition.

1.5 OBJECTIVES

The objectives for natural convection in square enclosure with partition on top wall are:

i. To solve natural convection problem numerically by predicting the streamlines and isothermal lines.
ii. To compare the numerical and existing experimental result for natural convection.
iii. To predict natural convection phenomena at different conditions with double partition, different partition location and different partition height.

1.6 SCOPE

i. Laminar air flow in a two dimensional square enclosure.

ii. Steady state condition.

iii. Partition is available on top wall.

CHAPTER II

LITERATURE REVIEW

2.0 INTRODUCTION

The main objective for this chapter is to find more detailed information and previous work of other researcher on numerical method of natural convection in square partition on top wall. There are several issues and parameters need to consider as being discussed in journals and books.

2.1 NATURAL CONVECTION IN SQUARE ENCLOSURE

Due to temperature difference, thermal energy will transfer from one point to another. This phenomenon is called heat transfer (Cengel, 2008). There are three types of heat transfer process modes that will involve due to medium of temperature gradient. Conduction heat transfer modes is a term used for temperature that pass through solid and stationary liquid while convection heat transfer is mode for temperature gradient at moving fluid and surface. For radiation modes which is the third mode is occur between two surfaces where net radiation of heat will exchange (Incropera *et al*, 2007)

By focusing more on convection modes, this mode can be divided into external and internal forced convection. Three types of convection flow are free, force and mixed

flow convection. Free flow can be defined as flow of fluid that happen due to buoyancy force which is not involving any other element. Force convection flow is flow which is involving external element acting as force to continuously providing force for temperature gradient. Mixed convection flow is result of free or natural convection flow with force convection flow in order for temperature gradient (Incropera *et al*, 2007)

As being applied in engineering, geometry shapes of enclosure is one of the important criteria that will be giving effect to flow of fluid. Square cavities, concentric cylinder and as in Figure 2.2 concentric spheres are several example of geometries shape that commonly used. Raithby and Hollands were persons that considered free convection in heat transfer for concentric cylinder which is more focusing on horizontal type and concentric spheres. Square cavities in Figure 2.1 have widely reviewed either in experimental or theoretical method. Due to this reason, the research will be narrowed in square enclosure to determined the fluid flow result in numerical (Incropera *et al*, 2007)

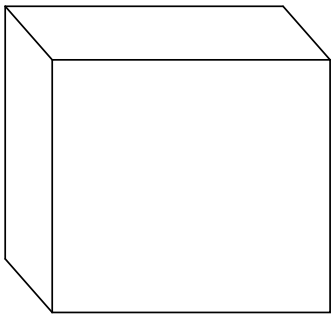

Figure 2.1 Square cavity

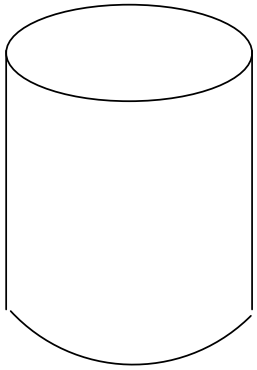

Figure 2.2 Concentric cylinder