

Heat Transfer Enhancement in Vertical Narrow Plates by Natural Convection

Dr.Ch.S.Naga Prasad¹

Professor & Principal Dept. of Mech, GIITS Engineering College, Aganampudi; Visakhapatnam (DT), A.P, India

ABSTRACT: Heat transfer is the area that deals with the mechanism responsible for transferring energy from one place to another when a temperature difference exists. Natural convection is one of the most economical and practical methods of cooling and heating. Natural convection is caused by temperature or concentration induced density gradient within the fluid. This study deals with the study of natural convection in horizontal plate with and without vertical confining walls. The parameters varied during the experimentation are heat input, aspect ratio (the ratio of gap of horizontal plate with respect to vertical plate and gap of horizontal plate from bottom to top). The present study aims to determine the heat transfer characteristics, along the plate for the selection of optimum dimension for design purpose. CFD analysis is to determine the pressure drop, velocity, heat transfer rate and mass flow rate for the both horizontal and vertical narrow plates at different angles (0° , 30° , 45° & 60°). Thermal analysis is to determine the heat flux and temperature distribution for different materials (aluminum, copper & steel).

KEYWORDS: Finite element analysis, vertical narrow plates, CFD analysis, thermal analysis.

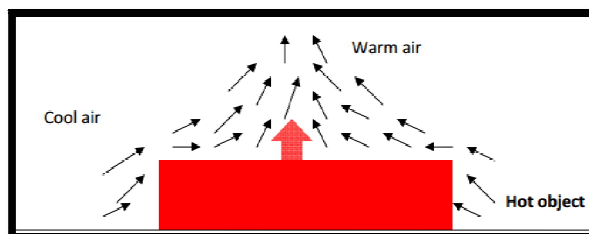
I.INTRODUCTION

Natural Convection:

In natural convection, the fluid motion occurs by natural means such as buoyancy. Since the fluid velocity associated with natural convection is relatively low, the heat transfer coefficient encountered in natural convection is also low.

Mechanisms of Natural Convection:

Consider a hot object exposed to cold air. The temperature of the outside of the object will drop (as a result of heat transfer with cold air), and the temperature of adjacent air to the object will rise. Consequently, the object is surrounded with a thin layer of warmer air and heat will be transferred from this layer to the outer layers of air.



The temperature of the air adjacent to the hot object is higher, thus its density is lower. As a result, the heated air rises. This movement is called the natural convection current. Note that in the absence of this movement, heat transfer would be by conduction only and its rate would be much lower. In a gravitational field, there is a net force that pushes a light fluid placed in a heavier fluid upwards. This force is called the buoyancy force.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

II. LITERATURE REVIEW

HEAT TRANSFER ANALYSIS OF TWO ADJACENT NARROW PLATES

Numerical and analytical studies of the interaction of the natural convective flows over two adjacent vertical and inclined narrow isothermal flat plates in the laminar flow region has been discussed. In the present work two cases are considered. In one case, the plates are horizontally adjacent to each other, the plates being horizontally separated while in the other case, one plate is symmetrically placed above the other plate the plates being vertically separated. Attention has been given to the effects of the inclination angle of the plates to the vertical, to the effects of the vertical or horizontal dimensionless gap between the heated plates, and to the effects of the dimensionless plate width on the mean heat transfer rates from the two heated plates for a wide range of Rayleigh numbers. Empirical equations for both the case of horizontally separated and vertically separated plates have been given. Thermal analysis and CFD analysis has carried in Ansys for above cases and 3D models are drawn in Pro/Engineer. Thermal analysis is done on the horizontally separated plates and vertically separated plates for two materials Aluminum and Copper. By observing the results, the heat transfer rate is more for horizontally separated plates than vertically separated and copper has high heat transfer rates. The Nusselt number is increasing for horizontally separated plates which mean that the heat transfer coefficient is more thereby more heat transfer rates.

III. PROBLEM DESCRIPTION

The objective of this project is to make a 3D model of the narrow plates and study the CFD and thermal behavior of the plates by performing the finite element analysis. 3D modeling software (PRO-Engineer) was used for designing and analysis software (ANSYS) was used for CFD and thermal analysis.

The methodology followed in the project is as follows:

- Create a 3D model of the horizontal plates using parametric software pro-engineer.
- Convert the surface model into Para solid file and import the model into ANSYS to do analysis.
- Perform thermal analysis on the plates assembly for thermal loads.
- Perform CFD analysis on the existing model of the surface of the plates for Velocity inlet to find out the mass flow rate, heat transfer rate, pressure drop.

IV. INTRODUCTION TO CAD/CAE

Computer-aided design (CAD), also known as **computer-aided design and drafting (CADD)**, is the use of computer technology for the process of design and design-documentation.

INTRODUCTION TO PRO-ENGINEER: Pro/ENGINEER Wildfire is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create exceptional products.

Different modules in pro/engineer

Part design, Assembly, Drawing & Sheet metal.

INTRODUCTION TO FINITE ELEMENT METHOD: Finite Element Method (FEM) is also called as Finite Element Analysis (FEA). Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining approximate solutions. Finite element method being a flexible tool is used in various industries to solve several practical engineering problems. In finite element method it is feasible to generate the relative results.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

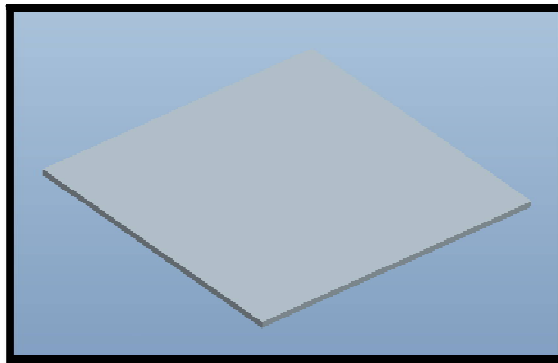
Vol. 6, Issue 4, April 2017

V. RESULTS AND DISCUSSIONS

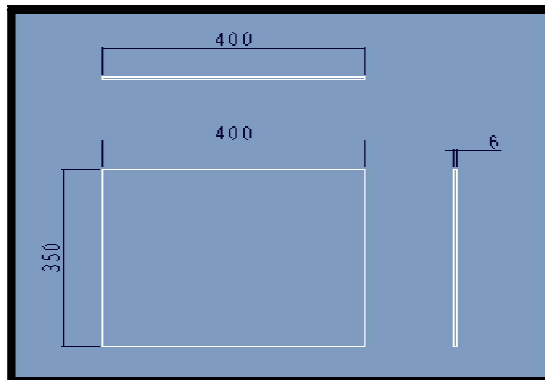
Models of narrow plate using pro-e wildfire 5.0:

The plate is modeled using the given specifications and design formula from data book. The plate outer casing body profile is sketched in sketcher and then it is extruded by using extrude option.

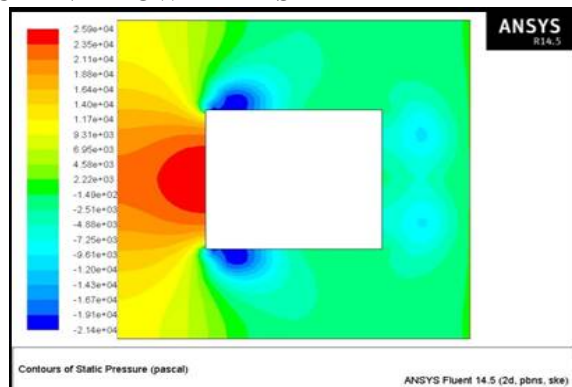
Narrow plate 3D model



Narrow plate 2D model



CFD ANALYSIS OF VERTICAL NARROW PLATES



International Journal of Innovative Research in Science, Engineering and Technology

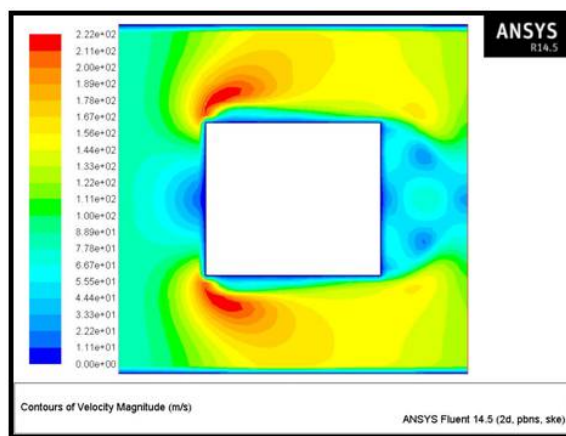
(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

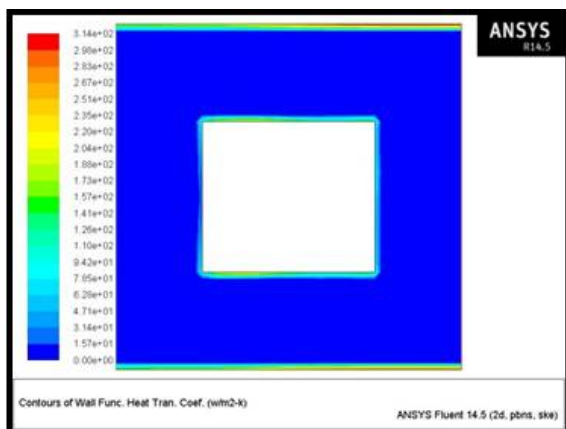
According to the above contour plot, the maximum static pressure at inlet of the narrow plate because the applying the boundary conditions at inlet of the boundary and minimum static pressure at the adjacent sides of the narrow plate. According to the above contour plot, the maximum pressure is $2.50e+04\text{Pa}$ and minimum static pressure is $-2.14e+04\text{Pa}$.

VELOCITY



According to the above contour plot, the maximum velocity magnitude of the air at corners of narrow plate, because the applying the boundary conditions at inlet of the boundary of the narrow plate and minimum velocity magnitude at around edges of the narrow plate. According to the above contour plot, the maximum velocity is $1.11e+01\text{m/s}$ and minimum velocity is $2.22e+02\text{m/s}$.

HEAT TRANSFER CO-EFFICIENT



According to the above contour plot, the maximum heat transfer coefficient of the air at edges of the narrow plate and minimum heat transfer coefficient between around the boundary edges and narrow plate edges. According to the above contour plot, the maximum heat transfer coefficient is $3.14e+02\text{w/m}^2\text{-k}$ and minimum heat transfer coefficient is $1.57e+01\text{w/m}^2\text{-k}$.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

MASS FLOW RATE

Mass Flow Rate	(kg/s)
inlet	79.311401
interior-trn_srf	196.93365
outlet	-79.3256
wall-trn_srf	0
Net	-0.014198303

HEAT TRANSFER RATE

Total Heat Transfer Rate	(w)
inlet	5974630.5
outlet	-6031706
wall-trn_srf	0
Net	-57075.5

THERMAL ANALYSIS OF VERTICAL PLATES

Used Materials Copper, Aluminum alloy 6061 & aluminum alloy 7075

MATERIAL PROPERTIES:

Copper material properties

Thermal conductivity = 385w/m-k

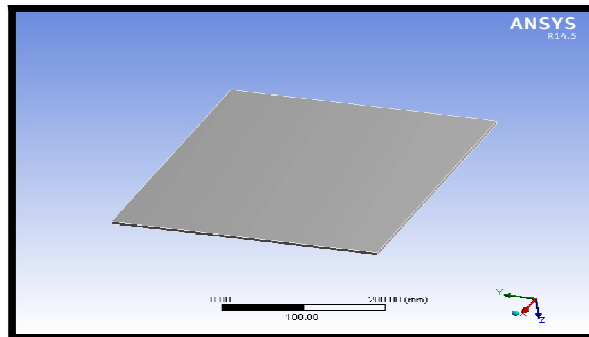
Aluminum alloy material properties

Thermal conductivity = 30.0w/m-k

Steel material properties

Thermal conductivity = 50.2 w/m-k

IMPORTED MODEL



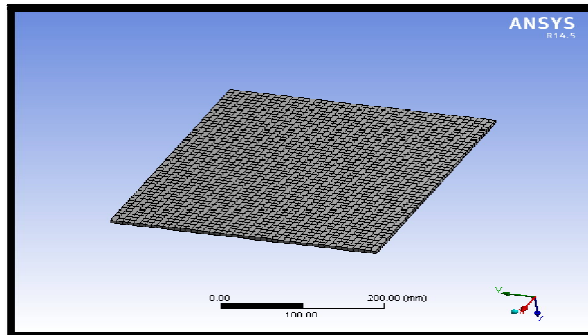
International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

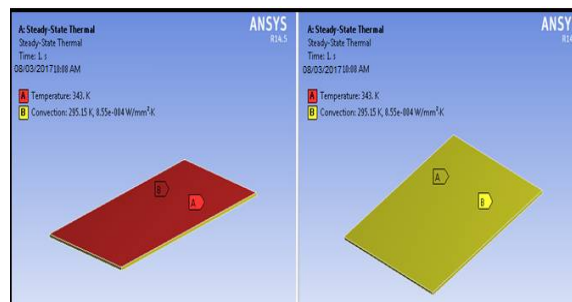
Vol. 6, Issue 4, April 2017

MESHED MODEL

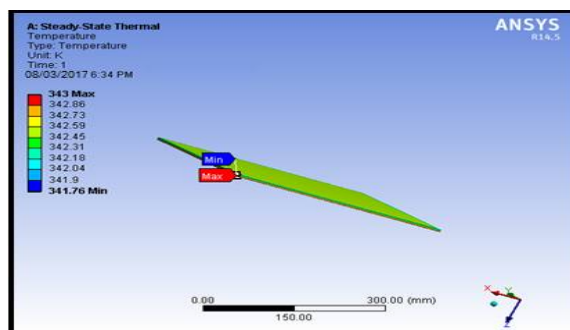


Finite element analysis or FEA representing a real project as a “mesh” a series of small, regularly shaped tetrahedron connected elements, as shown in the above fig. And then setting up and solving huge arrays of simultaneous equations. The finer the mesh, the more accurate the results but more computing power is required.

BOUNDARY CONDITIONS



MATERIAL – COPPER TEMPERATURE



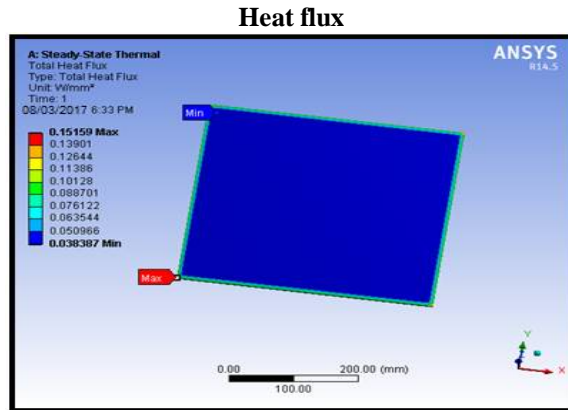
According to the contour plot, the temperature distribution maximum temperature at bottom of the narrow plate because the temperature passing from the bottom of the plate. So we are applying the temperature bottom of the plate and applying the convection except bottom of the plate.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017



According to the contour plot, the maximum heat flux at corner portion of the narrow plates. Minimum heat flux except corners of the narrow plates.

According to the above contour plot, the maximum heat flux is 0.15657 w/mm^2 and minimum heat flux is 0.039277 w/mm^2 .

VI RESULTS AND DISCUSSIONS

CFD ANALYSIS RESULT TABLE

Reynolds number	Models	Pressure (Pa)	Velocity (m/s)	Heat transfer co-efficient ($\text{w/m}^2\text{-k}$)	Mass flow rate (kg/s)	Heat transfer rate (W)
2×10^6	0^0	2.59×10^4	2.22×10^2	3.14×10^2	0.0141983	57075.5
	30^0	3.25×10^4	2.80×10^2	3.39×10^2	0.13510132	2022.375
	45^0	6.49×10^4	3.40×10^2	4.06×10^2	0.246078	3677.875
	60^0	1.16×10^5	5.01×10^2	4.93×10^2	0.50804138	9873.625
4×10^6	0^0	1.03×10^5	4.44×10^2	5.52×10^2	0.02565	120081
	30^0	1.31×10^5	5.60×10^2	5.96×10^2	0.86120605	12874.25
	45^0	2.57×10^5	6.80×10^2	7.09×10^2	0.611465	9129
	60^0	4.65×10^5	1.00×10^3	8.55×10^2	1.05348	20294.25

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

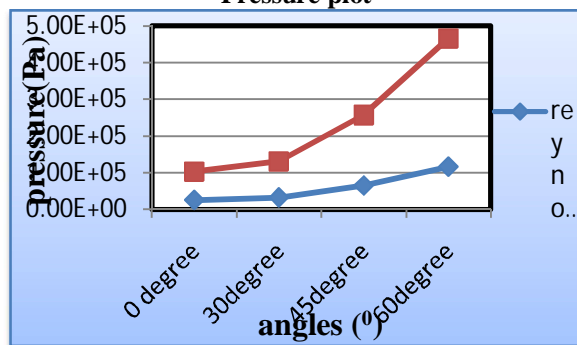
Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

THERMAL ANALYSIS RESULT TAB

Models	Materials	Temperature (⁰ C)		Heat flux (w/mm ²)
		Max.	Min.	
0 ⁰	Steel	343	333.99	0.14103
	Aluminum	343	339.2	0.15159
	Copper	343	341.76	0.15657
30 ⁰	Steel	343	331.7	0.17153
	Aluminum	343	338.22	0.18744
	Copper	343	341.41	1.1951
45 ⁰	Steel	343	329.74	0.20385
	Aluminum	343	341.08	0.23701
	Copper	343	337.26	0.22608
60 ⁰	Steel	343	325.73	0.3144
	Aluminum	343	335.2	0.35993
	Copper	343	340.34	0.38359

**GRAPHS
CFD ANALYSIS
Pressure plot**



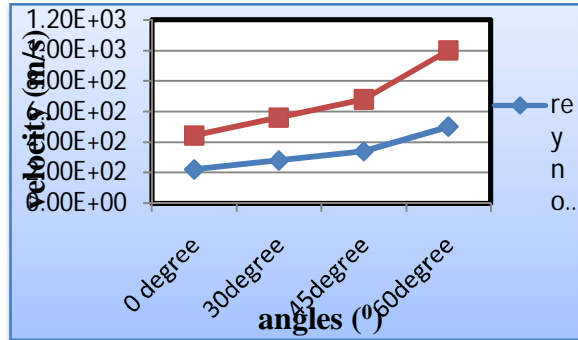
Velocity plot

International Journal of Innovative Research in Science, Engineering and Technology

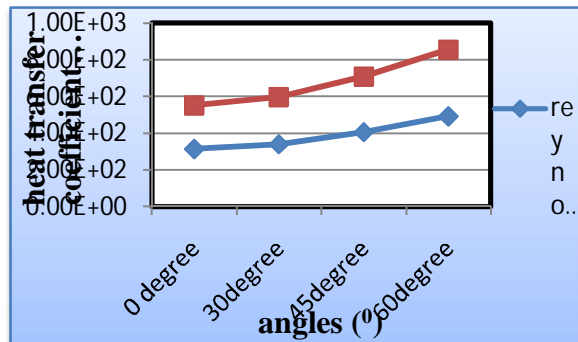
(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

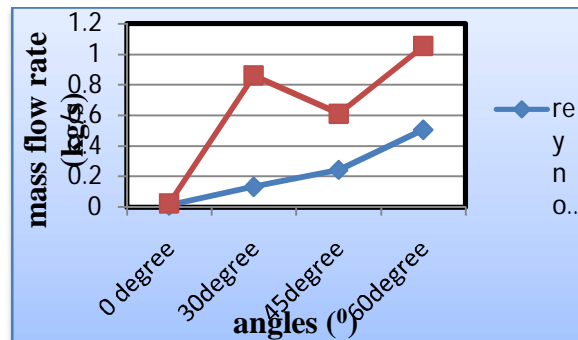
Vol. 6, Issue 4, April 2017



Heat transfer coefficient plot



Mass flow rate plot



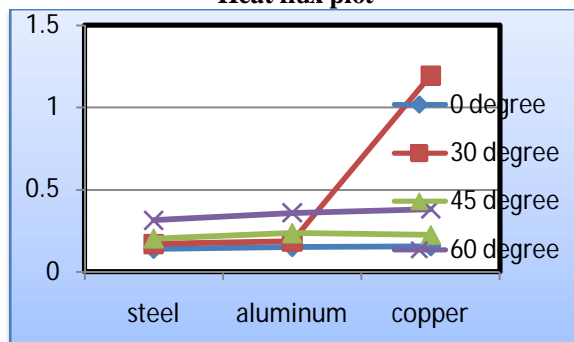
International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

THERMAL ANALYSIS Heat flux plot



VII. CONCLUSION

This study deals with the study of natural convection in horizontal plate with and without vertical confining walls. The parameters varied during the experimentation are heat input, aspect ratio (the ratio of gap of horizontal plate with respect to vertical plate and gap of horizontal plate from bottom to top). The present study aims to determine the heat transfer characteristics, along the plate for the selection of optimum dimension for design purpose. By observing the CFD analysis results the pressure drop, velocity, heat transfer coefficient and mass flow rate values are increases by increasing the vertical narrow plate angles. And heat transfer rate more at narrow plate angle 0 degree. By observing the thermal analysis results the heat flux more for copper material at 60⁰ angle of vertical narrow plate.

REFERENCES

- 1.Elenbaas W.(1942): "Heat dissipation of Parallel plates by free Convection", Physica 9, pp.1-28.
- 2.Sparrow E.M. and Azevedo L.F.(1985)"Vertical channel natural convection spanning between the fully developed limit and the single plate boundary layer limit", International Journal of Heat Mass transfer, Vol.28, No.10, pp. 1847-1857.
- 3.Said, S.A.M. and Krane R.J.(1990): "Ananalytical and experimental investigation of Natural Convection Heat Transfer in vertical channels with single obstruction", International Journal of Heat Mass Transfer, Vol.33, No.6, pp. 1121-1134.
4. Kihm,K.D.,Kim,J.H.and Fletcher,L.S.(1993): "Investigation of Natural Convection Heat Transfer in Converging Channel Flows Using a Specklegram Technique", Journal of Heat Transfer, Vol.115, pp. 140-14.
- 5.Kihm,K.D.,Kim,J.H.and Fletcher,L.S.(1995): "Onset of Flow Reversal and Penetration Length of natural Convective Flow Between Isothermal Vertical Walls", Journal of Heat Transfer, Vol.117, pp. 776-779.
6. Naylor, D., and Tarasuk, J. D.(1993):"Natural Convective Heat Transfer in adivided vertical channel Part-II-Experimental study", Journal of HeatTransfer, Vol.115, pp. 387-397.

BIOGRAPHY



DR.CH.S.Naga Prasad received his M.Tech Degree on Heat power Refrigerator and AC from JNTU, Anantapur in 2002 and Ph.D on IC Engines (Thermal Engg) from JNTU, Hyderabad in 2011. He is currently working as Professor & Professor in GONNA Institute of Information Technology and science, Aganampudi Visakhapatnam (Dt), A.P, INDIA.