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HEAT TRANSFER ENHANCEMENT IN PLATES BY NATURAL CONVECTION WITH AND WITHOUT VERTICAL CONFINING WALLS

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ABSTRACT

Natural Convection flow in a vertical channel with internal objects is encountered in several technological applications of particular interest of heat dissipation from electronic circuits, refrigerators, heat exchangers, nuclear reactors fuel elements, dry cooling towers, and home ventilation etc.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. Further, the influences of aspect ratio on the performance characteristics of heat transfer will be studied.

KEYWORDS: Natural convection, horizontal plate, vertical confining walls, aspect ratio,

INTRODUCTION

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. Natural convection flow occurs as a result of influence of gravity forces on fluids in which density gradients have been thermally established.

In a smooth vertical parallel plate channel that are open to the ambient at top & bottom ends, natural convection occurs when at least one of the two plates forming the channel is heated or cooled. The resulting buoyancy-drive flow can be laminar or turbulent depending upon the channel geometry; fluid properties & temperature difference of the plate & the ambient. The Rayleigh number in vertical channel is different that from flow over a vertical flat plate. Due to modern application of cooling of electronic components such as printed circuit boards, there has been resurgence of interest in studying natural convection in vertical channels. Understanding the flow and heat transfer pattern in this equipment may significantly improve their design & consequently their operational performance.

Elenbaas[1] conducted the first comprehensive experimental work, which has served as a benchmark for most subsequent studies. Laminar natural convection heat transfer in smooth parallel –plate vertical channels was investigated and a detailed study of the thermal characteristics of cooling by natural convection was reported. This work was followed by many experimental, theoretical and numerical investigations for both laminar and turbulent flow regimes which were discussed below. The literature can be classified in two classes; i.e. experimental and numerical investigations in laminar flow regimes and in turbulent flow regimes.

During the last two decades, a number of studies involving experimental measurements of heat transfer in laminar free convection flows between two vertical plates were reported.

Sparrow and Azevedo [2] conducted experimental and numerical studies on the effect of inter-plate spacing on natural convection heat transfer characteristics of a one sided heated vertical channel. The 50 fold variations of inter-plate spacing enabled the investigation between the two limits of fully developed channel flow and single vertical plate. The experiments were performed in water at Prandtl number Pr=5. The numerical solutions were carried out by taking into account both natural convection in

the channel and conduction at the wall. It was reported that the heat transfer process is particularly sensitive to changes in inter-plate spacing for narrow channels. The problem of natural convection heat transfer in a vertical channel with a single obstruction was investigated both experimentally and analytically by Said and Krane [3]. Optical techniques were used to obtain measurement of both quantitative data (heat flux and temperature) and qualitative data (flow visualization), with uniform wall temperature boundary conditions in experimental investigation. In the numerical study, finite element computer code NACHOS was used with the two thermal boundary conditions of uniform wall temperature and uniform heat flux. It concludes that the location of the obstruction along the wall affects the rate of heat transfer. Moving the obstruction away from the entrance towards the exit was found to reduce the net heat transfer rate from the channel.

Kihm [4] investigated natural convection heat transfer characteristics in converging vertical channels flows by measuring the wall temperature gradients using a laser speckle gram technique. The local and average heat transfer coefficients were obtained for forty different configurations, including five different inclination angles from the vertical ($\theta= 0^0$, 15^0, 30^0, 45^0 and 60^0) with eight different channel exit openings for each inclination angle. Correlations were obtained for local and average heat transfer coefficients in the range of Grashof numbers up to $7.16 \times 10^{6;}$ however the flow regimes for all considered cases were laminar. It reported that as the top opening of channel decreased, both local and average Nusselt number values started decreasing below that of a single plate. In low Rayleigh number range, neither the single plate limit nor the fully developed limit could properly describe the heat transfer characteristics in the converging channel.

In another study Kihm [5] investigated the phenomenon of flow reversal in natural convection flow between two isothermal vertical walls. They reported the existence of a recirculating flow region accompanied by vena-contracta like streamlines at the entrance when Rayleigh number exceeded a certain critical value. These results in, insufficient volume flow rate through the channel, which in turn, limited the increase of heat transfer as Rayleigh number increases.

Naylor and Tarasuk (PartII) [6] conducted an interferometric study on two dimensional laminar natural convection in an isothermal vertical divided channel for two different positions of the dividing plate. The average Nusselt number obtained experimentally was found to be 10% less than the one obtained numerically (Naylor and Tarasuk (PartII, 1993).

Tanda [7] experimentally investigated the problem of heat transfer between two staggered vertical plates in the presence of natural convection regime with the effect of inter plate spacing and magnitude of vertical stagger on the heat flux from each plate. The experiments were performed in air and thermal field characteristics obtained using a schlieren optical technique. They reported that staggering affects the heat transfer characteristics of the facing sides of the plates when the interplate distance was relatively small. The Nusselt number averaged on the inner face of the lower plate was enhanced up to over 40% with that for the case of the unstaggered plate channel. On the other hand, the mean Nusselt number on the facing side of the upper plate was reduced by 15%.

Manca [8] performed experimental study of laminar natural convection in an asymmetrically heated vertical channel with uniform flush mounted discrete heat sources. The effect of wall emissivity was taken into account. The wall temperature profiles as a function of emissivity, strip heat flux, channel spacing, the number strips and their arrangement were presented. A correlation for Nusselt number in terms of Rayleigh number was proposed for Rayleigh numbers ranging from 10 to 106.

Tanda [9] experimentally studying heat transfer in natural convection flow of air in a vertical channel with one surface roughened by transverse square ribs while the opposite surface kept smooth. Isothermal condition was imposed on the ribbed side, while the other side remains unheated. A schlieren optical technique was used for measuring the thermal field characteristics and for obtaining the distribution of the local heat transfer coefficient. It was found that he presence of the square ribs results in lower heat transfer in comparison with the smooth channel.

Daloglu and Ayhan [10] who conducted measurements of natural convection in a rectangular channel with fins connected periodically to both plates. The channel had an aspect ratio of 66 and the walls are maintained at uniform heat flux. Results were obtained for the modified Rayleigh numbers ranging from 20 to 90 and it was found that the Nusselt number for finned channels is less than that for smooth channels for all values of Rayleigh number.

Fujii [11] study on natural convection from an array of vertical plates with discrete and protruding heat sources. The governing equations of motion and energy were solved numerically using an upwind finite difference scheme for Grashof numbers up to 8.8×10^5. The velocity profiles between the central plates were measured using laser-doppler anemometer while the

plate surface temperature was measured using thermocouples. A correlation for the local Nusselt number was proposed that is capable of predicting the protrusion surface temperature within an error band of ±20%.

C.E.Kwak and T.H.Song [12] investigated natural convection from two dimensional vertical plates with horizontal rectangular grooves both experimentally and numerically. A mach-Zehnder interferometer was used in the experiment and local Nusselt number at each groove surface (outer, bottom, inner and top surface) were measured quantitatively from the interferograms.The effect of Rayleigh number for each aspect ratio was studied. The results were summarized using the average nusselt number Vs Rayleigh number correlations. The correlations may be used for selecting proper aspect ratio and dimension.

A.La Pica [13] studied experimentally the free convection of air in a vertical channel in a laboratory model of height (H) = 2.6m and rectangular cross section b × s; with b = 1.2m and the channel width s variable. One of the channel walls is heated with a uniform heat flux. Tests are made with different values of channel gap and heating power (s = 7.5, 12.5, 17cm and q_c = 48 to 317 w/m^2). The following correlations are developed and the geometrical parameter s/H;

$Nu = 0.9282R_a^{0.2035} (s/H)^{0.8972}$
$Re = 0.5014R_a^{0.3148} (s/H)^{0.418}$

M.Miyamoto and Y. katoh [14] numerically investigated free convection heat transfer from vertical and horizontal short plates using finite difference method. The present results regarding average Nusselt number on vertical and horizontal thin plates can be closely approximated by the following equation.

For vertical thin plate
$N_{uL} = 0.448 + 0.46G_{rL}^{1/4}$, Pr=0.72 and $15 \leq G_{rL} \leq 27000$
$N_{uLD} = 0.353 + 0.509G_{rD}^{1/5}$, pr = 0.72 and $4 \geq G_{rD} \geq 27000$

The average Nusselt number on the vertical plate (height = l) with finite thickness (d) can be approximated by the above correlation for a thin vertical plate with an error within about 6% using characteristic length (l+d) in both Nusselt and Grashof numbers instead of l in the range L ≥5 and D≤ 10, where L= dimensionless plate height and D= dimensionless plate thickness.

Naylor [15] conducted numerical study on developing free convection flow between isothermal vertical plates with aspect ratios between 10 and 24. The Navier-stokes and energy equations were solved numerically assuming a special inlet flow boundary conditions in the range of Grashof number $50 \leq Gr \leq 5\times10^4$. The results showed a new recirculating flow zone in the entrance region when Gr = 104 for a channel of length to width ratio of 24. At low Rayleigh number, the flow entered the channel without separation; however, in the high Rayleigh number range separation occurred followed by the formation of small eddies close to the channel wall near the leading edge. As aspect ratio increases, flow separation was found to occur for lower values of Rayleigh numbers.

Naylor and Tarasuk [16] obtained a numerical solution for the problem of two dimensional laminar natural convection in a divided vertical channel. The channel was dividing by an isothermal vertical plate located midway between the two isothermal channel walls. The study examined the effect of Rayleigh number, plate to channel length ratio, vertical plate position and the plate thickness on the heat transfer process. Navier-stokes and energy equations were obtained for Prandtl number Pr=0.7. Positioning the plate at the bottom of the channel was found to give the highest average Nusselt numbers for the plate and channel. The average Nusselt number on the dividing plate was about two times higher than that of a single plate placed in a fluid of infinite extent.

Further investigations on the separation bubble formed near the channel entrance region were carried out by Roberts and Floryan [17]. This separation bubble was found to have a considerable effect on the local Nusselt number especially at high Grashoy numbers. When this sharp-edged inlet corners were rounded, the inlet separation region disappeared for all Grashof numbers. It was found that the local Nusselt number decreases in the entrance region of the channel with square corners but with no such decrease in case of rounded corners.

The effect of other parameters including different forms of heating, transient regimes, chimney effect and channel geometry were investigated by a number of researchers. Shahin and Floryan [18] studied the heat transfer enhancement generated by the chimney effect in a system of vertical channels. The increase in heat transfer with adiabatic chimneys was studied numerically and a heat transfer correlation was presented.

Chang [19] performed numerical analysis of transient natural convection in vertical plates of finite length with transient symmetric isoflux heating. The parameters studied were the Grashof number ranging from 10 to 108 for aspect ratio 5. The transient thermal and flow fields, including isotherms, pressure contours, streamlines and velocity profiles for various Grashof number were obtained. A correlation of a transient induced Reynolds number for a vertical finite

length channel with various transient Rayleigh numbers was proposed.

Other form of heating was reported in the work by Lee [20] who conducted numerical investigation on laminar natural convection heat and mass transfer between two vertical parallel plates with unheated entry and exit regions. Both with uniform wall temperature/concentration and uniform wall heat flux/mass flux as boundary condition. Results of dimensionless induced flow rate, average Nusselt number, Sherwood number were reported and correlations for these parameters were presented.

Straatman [21] investigated the effect of the angle of inclination on natural convection heat transfer in a channel with isothermal walls. The overall heat transfer was found to decrease as the inclination angle increased. The amount of decrease in heat transfer was proportional to the cosine of the inclination angle.

The heat flux distribution along each wall was presented. No significant thermal field was observed in the considered range of the parametric studies.

Said [22] conducted numerical investigation of natural convection heat transfer in a uniform convergent vertical channel with air as the working medium. Half angle of convergence in the range of 0^0 to 10^0 was employed and solutions were obtained for modified Rayleigh number ranging from 1 to 2×10^4. To obtain a correlation for Nusselt number suitable for merging the convergent channel results with those of the parallel walls channel, three characteristic dimensions based on the minimum, average and maximum channel interval spacing were considered. It was found that the maximum interval spacing is the most appropriate as a characteristic dimension.

Miyamoto [23] conducted the first experimental study on turbulent free convection heat transfer in an asymmetrically heated vertical channel. The channel was formed from two vertical parallel plates. One plate was heated by imposing a uniform heat flux along the plate and the opposite plate was adiabatic. The channel

(4.98m high and spanned 0.95m) was open at the bottom and top. Experiments were performed with channel widths of 50, 100 and 200mm. The temperature variation on the heated and adiabatic vertical plates as well as the turbulence characteristics of the free convection flow between the plates were measured. These results were compared with those of a single plate. The temperature and velocity fields were presented at three vertical locations and the variation of the local heat transfer coefficient was determined along the heated wall.

La Pica [24] conducted an experimental study of free convection heat transfer in a vertical channel of rectangular cross section, with a wall of breadth 1.2m and variable channel width and a fixed height of 2.6m. One of the channel walls was heated with uniform heat flux. Tests were conducted with different values of channel gap and heating power. On the basis of results obtained, two correlations were reported for the average Nusselt number in terms of Rayleigh number and a geometrical parameter (channel gap/channel height).

Habib [25] conducted velocity field measurements for natural convection flow in symmetrically and asymmetrically heated vertical channels. In symmetrically heated channel, both plates are heated above the ambient temperature where in the asymmetrically heated channel, one plate was kept above ambient temperature and the other one below it. Velocity measurements were performed for two Rayleigh numbers (Ra = 2×10^6 and 4×10^6) both in the turbulent region.

The literature survey indicates that enough work has not been carried out yet. Hence this work is undertaken.

PROPOSED WORK
The aim of the present work is to investigate experimentally the heat transfer by natural convection in horizontal plate with and without vertical confining walls. The details of the experimental set up are as follows.

Table-1 Details of experimental set-up

S.N.	Description	Dimensions/Range
1	Horizontal Plate (Mild Steel) 1no.	300×245×15mm
2	Vertical plate (Mild Steel) 2 no.	400×350×6mm
3	Heat input	20 – 300 W/m^2

The parameters varied during the experimentation are heat input, aspect ratio and horizontal plate with and without vertical confining walls. The temperatures at various locations of the plates are measured with the

help of calibrated PT-100 thermocouples. Heat input is supplied by the use of dimmer stat. The two vertical plates are kept as adiabatic walls and only heat is supplied to the horizontal plate

EXPERIMENTAL SET-UP

Fig1- Experimental set-up with and without vertical confining walls.

The experimental set-up consists of following instrumentation –

(i) Dimmer stat (0-260 Volt AC Supply)
(ii) Voltmeter (0 - 460 Volt)
(iii) Ammeter (0 - 5 Ampere)
(iv) Digital Temperature Indicator (DTI) of 12 port (Range $0 – 400^\text{o}C$)
(v) Four Pencil types' coils of diameter 10mm and length 53mm of 165 Watt each sandwiched in Horizontal plate.
(vi) Calibrated Thermocouples used PT-100 type – 12nos.

The parameters varied during the experimentation are:

- Heat input
- Aspect ratio (S) (i.e. the ratio of gap of horizontal plate with respect to vertical plate and gap of horizontal plate from bottom to top).

- The gap between horizontal and vertical plate is fixed as 6 cm, 3cm and the absence of vertical confining walls.
- The gap between horizontal and vertical plate is fixed as 6 cm and the vertical gap of horizontal plate from bottom is fixed as 7.5, 8.58, 10, 12, 15, 20 and 30cm.
- Aspect ratio (S) = 6/7.5 = 0.8, 6/8.58 = 0.7, 6/10 = 0.6, 6/12 = 0.5, 6/15 = 0.4, 6/20 = 0.3, 6/30 = 0.2 (i.e. When the gap between horizontal and vertical plate is 6cm).
- Similarly, the gap between horizontal and vertical plate is fixed as 3 cm and the vertical gap of horizontal plate from bottom is fixed as 7.5, 8.58, 10, 12, 15, 20 and 30cm.
- Aspect ratio (S) = 3/7.5 = 0.4, 3/8.58 = 0.35, 3/10 = 0.3, 3/12 = 0.25, 3/15 = 0.2, 3/20 = 0.15, 3/30 = 0.1 (i.e. When the gap between horizontal and vertical plate is 3cm).

Finally, the vertical gap of horizontal plate from bottom is fixed as 7.5, 8.58, 10, 12, 15, 20 and 30cm in the absence of vertical confining walls.
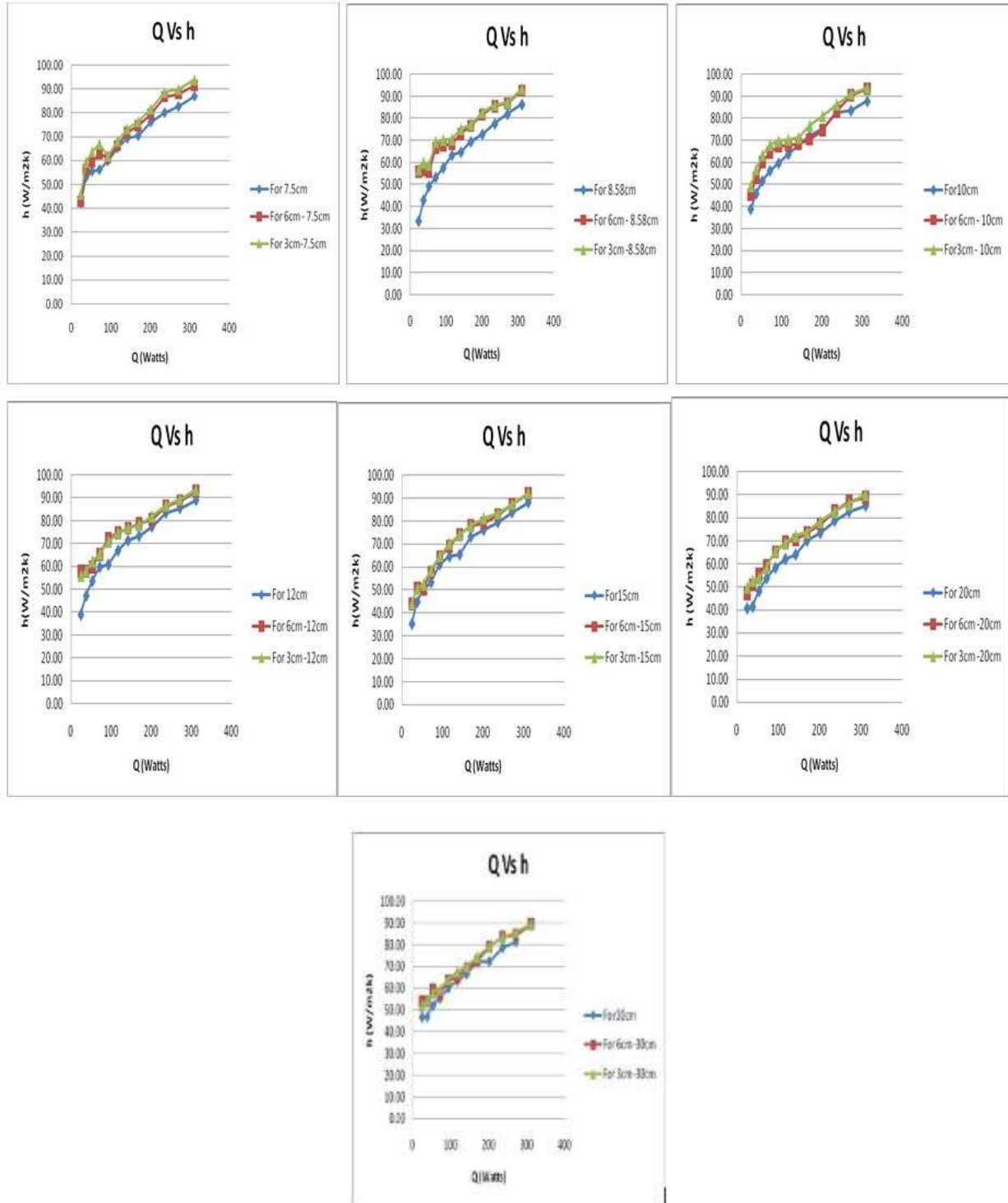
RESULTS
Heat Transfer Characteristics

Fig. 2 Comparison of Heat Transfer characteristics with and without vertical confining walls.

Fig. 2 shows the comparison of Heat Transfer Characteristics for with and without vertical confining walls. It has been observed that with the presence of vertical confining walls the heat transfer coefficient goes on increasing and this effect is attributed to chimney effect. As the heat flux increasing, the buoyancy effect also tends to increase and hence the heat transfer coefficient. Further, when the gap between horizontal and vertical plate is kept minimum i.e. 3cm, the heat transfer coefficient is more, this is due to fact that, for this configuration the flow of air is more steady and continuous

FUTURE WORK
The geometry of the horizontal plate will be varying by providing the v-slot, square slot, rectangular slot and circular grooves. This increase in surface area of the plate with varying geometry may increase the heat transfer rate considerably for various aspect ratios. Furthermore, these experimental results will be validated by CFD simulation (GAMBIT and FLUENT Software). Again the present work also aims to study and to develop a correlation in terms of Nu =c (Ra) n for horizontal plates with and without vertical confining walls.

CONCLUSION
The present study deals with the heat transfer characteristics of horizontal plate in vertical confining walls which will give maximum heat transfer rate when the gap between horizontal and vertical plate is minimum, as the flow of air will be more steady and continuous. Also this increase in heat transfer rate is contributed to chimney effect i.e. due to presence of vertical confining walls the rate of heat transfer is more as compared to free space. This study is particularly useful in design of cooling of various electrical and electronic components mounted on printed circuit boards, heat dissipation from electronic circuits, refrigerators, heat exchangers, nuclear reactors fuel elements, dry cooling towers, and home ventilation etc

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): "An analytical 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 a divided vertical channel Part-II-Experimental study", Journal of Heat Transfer, Vol.115, pp. 387-397.
7. Tanda G.(1995): "Experiments on Natural Convection from two staggered vertical plates", International Journal of Heat Mass Transfer, Vol.38, No.3, pp. 533-543.
8. Manca, O., Nardini, S., Naso, V. and Ruocco, G.(1995): "Experiments on Natural Convection and Radiation I asymmetrical heated vertical channels with discrete heat source", ASME, HTD- vol.317, No.1, pp. 309-319.
9. Tanda, G.(1997): "Natural Convection Heat Transfer in vertical channels with and without transverse square ribs", International Journal of Heat Mass Transfer, Vol.40, No.9, pp. 2173-2185.
10. Daloglu, A. and Ayhan, T.(1999): "Natural Convection in a periodically finned vertical channel", International Communications in Heat and Mass Transfer, Vol.26, no.8, pp. 1175-1182.
11. Fujii, M., gima, S., Tomimura, T., and zhang, X.(1996): "Natural Convection to air from an Array of vertical parallel plates with Discrete and protruding Heat Sources", International Journal of Heat and Fluid Flow, Vol.17, pp. 483-490.
12. Kwak, C. E. and Song, T. H.(2000): "Experimental and Numerical Study on Natural Convection from vertical plates with Horizontal Rectangular Grooves", International Journal of Heat and Mass Transfer, Vol.43, No.5, pp. 825-838.

13. La Pica, A., Rodono, G., and Volpes, R.(1993): "An experimental investigation on Natural Convection of air in a vertical channel", International Journal of Heat and Mass Transfer, Vol.36, No.5, pp. 611-616.

14. Miyamoto, M., katoh, Y., Kurima, J., Kurihara, S., and Yamashita, k.(1985): "Free Convection Heat Transfer from Vertical and Horizontal short plates", International Journal of Heat and Mass Transfer, Vol.28, No.9, pp. 1733-1745.

15. Naylor, D., Floryan, J. M., and Tarasuk, J. D.(1991): "A Numerical study of Developing Free convection Between Isothermal vertical plates", Transaction of the ASME, Journal of Heat Transfer, Vol.113, pp. 620-626.

16. Naylor, D., and Tarasuk, J. D.(1993): "Natural Convective Heat Transfer in a Divided vertical channel Part-I – Numerical

17. Study", Journal of Heat Transfer, Vol.115, pp. 377-387, 1993.Roberts, D. A., and Floryan, J. M.(1998): "Heat Transfer Enhancements in the Entrance zone of a vertical channel", ASME Journal of Heat Transfer, Vol.120, pp. 290-292.

18. Shahin, G.A., and Floryan, J. M.(1999): "Heat transfer Enhancement Generated by the Chimney effect in systems of vertical channels", ASME Journal of Heat Transfer, Vol.121, pp. 230-232.

19. Chang, kuo-Ping, hung and Ying-Huei.(1997): "Transient Natural Convection between vertical finite length heated plates", Journal of Thermo physics and Heat Transfer, Vol.11, No.2, pp. 203-211.

20. Lee, Kuan-Tzong(1999): "Natural Convection Heat and Mass Transfer in partially heated vertical parallel plates", International Journal of Heat and Mass Transfer, Vol.42, No.23, pp. 4417-4425.

21. Straatman, A. G., Naylor, D., Floryan, J. M., and Tarasuk, J. D.(1994): "A Study of Natural Convection between InclinedIsothermal plates", Journal of Heat Transfer, vol.116, pp. 243-245.

22. Said, S. A. M.(1996): "Investigation of Natural Convection in convergent vertical channels", International Journal of Energy Research, Vol.20, pp. 559-567.

23. Miyamoto, M., katoh, Y., Kurima, J., and Sasaki, H.(1986): "Turbulent Free Convection Heat Transfer from vertical parallel plates", Heat Transfer, proceeding of the International Heat Transfer, conference 8th.1986, Vol.4, pp. 1593-1598.

24. Habib, M. A., Ahmad, S. A., and Asghar, A.(2002): "Velocity Characteristics of Turbulent Natural Convection in Symmetrically and Asymmetrically heated vertical channels – Experimental Study", Thermal and Fluid Science, Vol.26, pp. 77-87.

25. Nada, S. A.(2007): "Natural Convection Heat Transfer in Horizontal and Vertical closed narrow enclosures with heated rectangular finned base plate", International Journal of Heat and Mass Transfer, Vol.50, Issues 3-4, pp. 667-679.

26. Ingrid Martorell, Joan Herrero and Francese Grau,(2003):"Natural Convection from narrow Horizontal plates at moderate Rayleigh numbers", International Journal of Heat and Mass Transfer, Vol.46, Issues 13, pp. 2389-2402.

27. Ruiz, R., and Sparrow, E. M.(1987): "Natural Convection in V-shaped and L-shaped corners", International Journal of Heat and Mass Transfer, Vol.10, Issues 12, pp. 2539-2548.

28. Edlabadkar, R. L., Sane, N. K., and parishwad, G. V.(2008): "Computational analysis of Natural Convection with Single V-type Partition plate", 5th European Thermal Sciences conference, Netherlands.

29. Sable, M. J., Jagtap, S. J., Patil, P. S., Baviskar, P. R., and Barve, S. B.(2010): "Enhancement of Natural Convection Heat Transfer on Vertical Heated Plate by multiple V-Fin Array", IJRRAS 5(2).

30. Hisanobu Kawashima and Yusuke Sakai,(2010):"Suppression of Natural Convection Heat Transfer along a vertical Flat Plate with periodic Circular grooves", International Symposium on Next Generation Air-conditioning and Refrigeration Technology, Tokyo, Japan.