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Analysis of Combined Convective Heat Transfer in Inverted T Shape Channel under Buoyancy – Assisting Flows Using Dimpled Pin Fin

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Abstract: ***Horizontal rectangular fin arrays are used for cooling of electronics components in the form of heat sink, in many situation a fan is mounted to increase the heat dissipation rate and thus there exist a problem of combined convection of horizontal rectangular fin array with this idea in mind the experiment setup was developed to work in the region of combined convection. The present paper also gives the effect of various velocities and power input on coefficients of heat transfer for combined convention using Al and Brass materials. The parameters considered are Reynolds number, Prandtl number, Nusselt number, heat transfer coefficient and heat transfer rate at various temperature difference. Two materials will be used i.e. Brass and Aluminium and parameter obtained will be compared for these two materials. With this limited objective the present work can be viewed as a starting step for carrying out for further research. The brass fins will be interest as a topic of research; however this requires very careful observation and adequate control on the parameter.***

Keywords: combined convection, assisting flow, Horizontal Rectangular Fin Array

1. Introduction

Heat transfer is a subject of widespread interest to the student of engineering curriculum, practicing engineers & technicians engaged in the design, construction, testing and operation of the many diverse forms of heat exchange equipments required in our scientific and industrial technology. Electrical engineers apply their knowledge of heat transfer for the design of cooling systems for motors, generators & transformers. Chemical engineers are concerned with the evaporation, condensation, heating & cooling of fluids. An understanding of the laws of the heat transfer flow is important to Civil engineers in the construction of dams, structures and to the architect, in the design of buildings. The Mechanical engineer deals with problems of heat transfer,in the field of internal combustion engines, steam generation, refrigeration and heating & ventilation.

To estimate the cost, the feasibility and size of the equipment necessary to transfer a specified amount of heat in a given time, a detailed heat transfer analysis must be made. The dimensions of boilers, heaters, refrigerators and heat exchangers depend not only on the amount of heat to be transmitted but rather on the rate at which heat is to be transferred under given condition.

A number of practical situation involve convection heat transfer, which is neither "forced" nor "free" in nature. The circumstances arise when a fluid is forced over a heated surface at rather low velocity. Coupled with the forced flow velocity is a convective velocity which is generated by the buoyancy forces and resulting reduction in fluid density near the heated surface. While calculating the heat transfer coefficient we can neglect the effect of natural convection, if velocity of fluid is sufficiently high ($v \geq 3.0$m/s). On the other hand of the velocity is very small ($v \leq 0.3$m/s) one can safely neglect the effect of forced convection. When the velocity is in the range ($0.3 \leq v \geq 3.0$) the combined convection occurs. Hence, the mixed convection can be defined as –"The situation in which free convection caused by buoyancy forces in fluid and forced convection imposed externally". e.g. By a pump or blower, are both necessary part of the description of the flow"

The general problem of combined convection heat transfer through rectangular finned surface has been studied extensively. Various geometrical arrangement & orientation have been also studied.

Khalil Khanafer [1] studied Mixed convection heat transfer in two-dimensional open-ended enclosures. Mixed convection heat transfer in open-ended enclosures has been studied numerically for three different flow angles of attack. Discretization of the governing equations is achieved using a finite element scheme based on the Galerkin method of weighted residuals. Comparisons with previously published work on special cases of the problem are performed and the results show excellent agreement. A wide range of pertinent parameters such as Grashof number,Reynolds number, and the aspect ratio are considered in the present study. The obtained results show that thermal insulation of the cavity can be achieved through the use of high horizontal velocity flow. Various results for the streamlines, isotherms and the heat transfer rates in terms of the average Nusselt number are presented and discussed for different parametric values.

Md. Mustafizur Rahman[2] investigated a study of mixed convection flow inside a rectangular ventilated cavity in the presence of a heat conducting square cylinder at the center has been carried out. An external fluid flow enters the cavity through an opening in the left vertical wall and exits from another opening in the right vertical wall. The governing equations are transformed into non-dimensional form and the resulting partial differential equations are solved by the

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finite element method. Results are presented in the form of average Nusselt number of the heated wall, average temperature of the fluid in the cavity and temperature at the cylinder center for the range of Richardson number and cavity aspect ratio. The streamlines and isothermal lines are also presented.

Rafeek Shaikh[3]studied Pulling Fins are extended surfaces employed to enhance the convective heat transfer from a surface for increasing heat dissipation Fins with various geometries have been designed and used in various cooling application the selection of particular fins configuration in any heat transfer application is an important state in designed process and takes into account the space, weight, manufacturing technique and cost consideration as well as the thermal characteristics it exhibits. Fins cross section profiles have profound influence on thermal characteristics of Annular Fins and the surface area changes with change of cross section of fins. This study deals with studying the performance of various available fins profiles. Widely used fins profile viz. Rectangular, Triangular, Trapezoidal, Circular, Rhombic, and Elliptical Fins. In Addition to the normal configuration of fins, to new configurations were designed and created. This includes length of each fins its thickness at the base and number of fins on each model this provided a basis for proper comparison of different fin profiles. The result were tabulated and studied for comparison of different fin profiles. The best performing fin was then selected on the basis of maximum heat dissipation from the circular model this study shows the performance of annular fins of different profiles under similar conditions and to quantify the heat losses and finally compare it with fin profiles on the basis of heat dissipation and thermal stress include. The fin profile were then arranged on the basis of performance.

S. V. Naidu [4] investigated The problem of natural convection heat transfer from fin arrays with inclination is studied experimentally and theoretically to find the effect of inclination of the base of the fin array on heat transfer rate. A numerical model is developed by taking an enclosure, which is formed by two adjacent vertical fins and horizontal base. Results obtained from this enclosure are used to predict heat transfer rate from the fin array. All the governing equations related to fluid in the enclosure, together with the heat conduction equation in both the fins are solved by using Alternate Direct Implicit method. Numerical results are obtained for temperature along the length of the fin and in the fluid in the enclosure. The experimental studies have been also carried out on two geometric orientations viz., (a) vertical base with vertical fins (vertical fin array) and (b) horizontal base with vertical fins (horizontal fin array), with the five different inclinations like 00, 300, 450, 600, and 900. The experimental results are compared with the numerical results computed by the theoretical analysis shows the good agreement.

Hasibur Rahman Sardar[5]studied dimples play a very important role in heat transfer enhancement of electronic cooling systems, heat exchangers etc. This work mainly deals with the experimental investigation of forced convection heat transfer over circular shaped dimples of different diameters on a flat copper plate under external laminar flow conditions. Experimental measurements on heat transfer characteristics of air (with various inlet flow rates) on a flat plate with dimples were conducted. From the obtained results, it was observed that the heat transfer coefficient and Nusselt number were high for the copper plate in which the diameter of dimples increases centrally in the direction of flow (case c) as compared to the other two cases.

W. L. Pu [6] studied The experimental results of mixed-convectionheat transfer in a vertical packed channel with asymmetricheating of opposingwalls are reported. The experiments were carried out in the range of $2 < Pe < 2200$ and $700 < Ra < 1500$.The measured temperature distribution indicates the existence of a secondary convective cell inside the vertical packed channel in the mixed-convection regime. A correlation equation for Nusselt number in terms of Peclet number Pe and Rayleigh number Ra was obtained fromexperimental data.A plot of Nu/Pe1/2 vs Ra/Pe exhibits the transition of heat-transfer results from the natural convection limit to the forced convection limit. The following three convection regimes exist: natural convection regime, $105 < Ra/Pe$; mixed-convection regime, $1 < Ra/Pe < 105$;and forced convection regime, $Ra/Pe < 1$

T. L. Chan, C. W. Leung [7] investigated An experimental study had been carried out to investigate the buoyancy-opposed mixed convection from an upward flow of hot air to a vertical pipe with a cooled surface. The investigation covered a wide range of flow regime, ranging from the ``free convection significant" to the ``forced convection significant" conditions. Reynolds number of the ¯ow extended from 966 to 14780, whereas the Buoyancy parameter, X [.Grd/(Red)2], varied from 0.008 to 2.77.A steady stream of hot air at a moderate pressure and a Prandtl number of 0.707 was arranged to flow upward through a vertical steel pipe, whose external wall was cooled uniformly by ambient air at 20°C. Test section of the vertical pipe was 1625 mm long with an internal diameter of 156 mm and an external diameter of 166 mm. Air temperature at inlet of the test section was varied from 40°C to 70°C. Both radial temperature and velocity profiles of the air flow were measured at inlet and exit of the test section respectively. Temperatures along the pipe wall were also measured. Non-dimensional expression for the prediction of the average heat transfer coefficient of the mixed convection from an upward flow of hot air to a vertical pipe with a cooled surface was developed from the experimental results. Convection heat transfer was found to impair when the ow is laminar and was enhanced for turbulent ow condition.

From the literature it is clear that combined convection with a few geometries only such as vertical plate with rectangular and circular cross section. However there are only a few studies reported on combined convection from other geometries such as dimpled fin arrays with different materials. The present project work was concerned with combined convection heat transfer for buoyancy assisting flow studies from horizontal dimpled rectangular fin array.

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2. Experimental Program

A. Experimental Apparatus

The actual experiential apparatus is shows in fig.1. in this apparatus two rectangular channels are used, one is horizontal and another is vertical. Horizontal rectangular dimpled fin array is used. Two types of fin material are used i.e Aluminium and Brassling chamber, a nozzle flow meter, a differential pressure transducer, a lab view data acquisition system and a test section and a heater unit. The setup also requires the provision for measurement of temperature of hot surface, ambient temperature. It should be possible to change input given to hot surface and velocity of fluid over the surface.

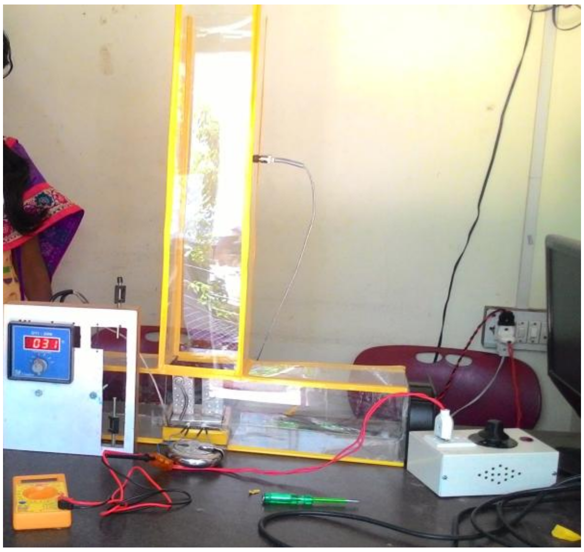

Figure 1: Actual experimental setup

B. Experimental Procedure

The experimental procedure of fin is very simple. The spacers were inserted in between vertical fins as per the requirements of spacing & tied together by using tie rods & nuts. Cartridge heaters were inserted in to the holes meant for them. This formed Horizontal fin array. This assembled array was bolted in enclosure to give undisturbed natural & forced convection environment when heated. The size of the enclosure was kept sufficiently larger than fin array. The heaters were connected in an electrically in parallel to circuit. Necessary electrical connections were made with dimmer stat, Voltmeter & Ammeter controlling & measurement purpose.

Copper constantan type thermocouples were used to measurement of temperature. The two dissimilar metal wires of each thermocouple were connected at different part in array to make the whole array as a junction for measurement of average temperature one thermocouple was used to measure the ambient temperature at extended boundaries within the encloseure. Other ends of the thermocouples are connected to a junction box from where the electrical connection is given to a digital temperature indicator. All experiments are carried out & many of them are repeated to ensure repeatability. The final observations are recorded only after reaching the steady state (T1,T2,T3,T4,Ta).

Where T is average pins temperature, T=T1+T2+T3+T4/4 and Ta is atmospherically temperature.

C. Observation Table

Observation table for Aluminium

S. No	Velocity (m/s) (v)	Power (watts)	T(0_C)	Ta (0_C)
1	0	24.42	47	30
	0.5	24.96	38.50	28
	1.0	26.17	39.5	29
	1.5	28.78	40.25	29
2	0	49.46	56.5	30
	0.5	46.14	48	29
	1.0	51.61	47.75	29
	1.5	51.95	47.75	29
3	0	79.40	66.5	29
	0.5	75.43	58.5	29
	1.0	76.6	53.5	29
	1.5	75.24	54.5	29

Observation table for brass

Sr No	Velocity (m/s) (V)	Power (watts)	T (0_C)	Ta (0_C)
1	0	24.76	47	29
	0.5	24.86	43.25	29
	1.0	26.17	38.5	29
	1.5	26.22	37.5	29
2	0	51.38	39.25	29
	0.5	50.80	50.25	29
	1.0	52.89	45.75	29
	1.5	48.84	43.25	29
3	0	75.68	63.5	28
	0.5	78.41	58.25	29
	1.0	76.66	53	29
	1.5	74.45	47	27

3. Results and Discussions

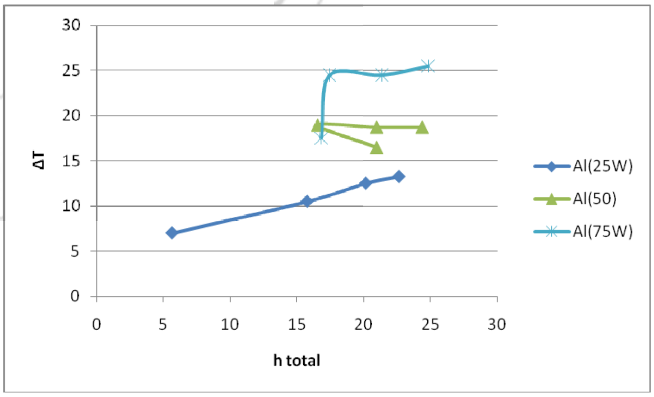

Figure 2: Total Heat transfer coefficient vs Temperature difference for aluminium with different power

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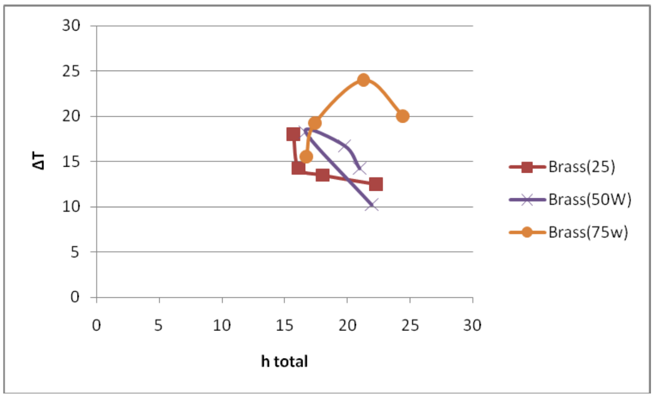


Figure 3: Total Heat transfer coefficient vs Temperature difference for Brass with different power

From fig.2 & 3 it is observed that heat transfer coefficient increases it increases of **ΔT,** as a result of increasing heat input. The graph for Natural convection is at the lower side. While the heat transfer coefficient increases with increase in the fluid velocity. It is expected that the brass fins should increases the temperature. With increase of the temperature difference is should decrease the heat transfer coefficient for the given heater input. Since there were problems of frequent power fluctuation and power failure, it was not possible to get the required steady state observation as are expected to furnish the useful information on the comparison of Al & brass fins under combined convection condition.

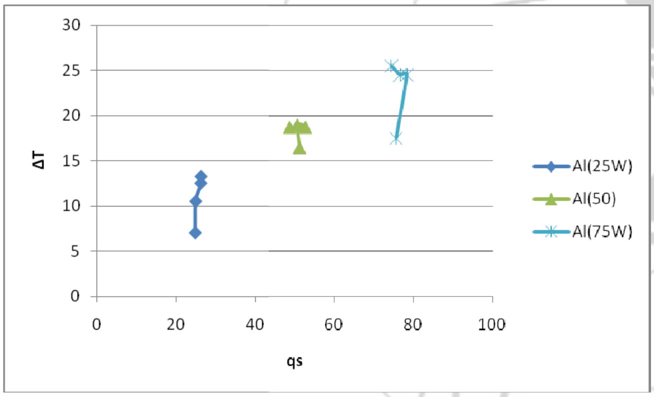
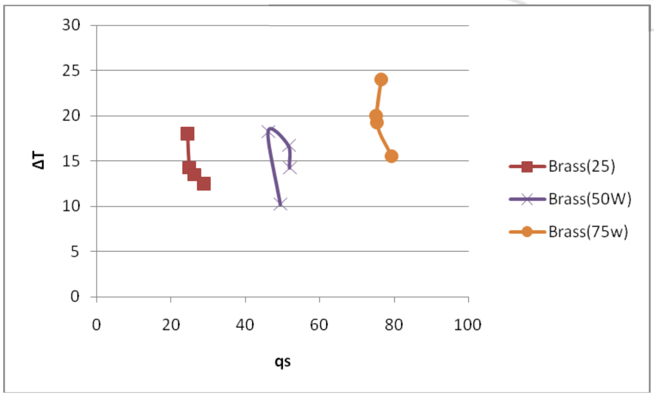


Figure 4: The variation of ΔT against the „q" input experimental for al



Figuer 5: The variation of ΔT against the „q" input experimental for Brass

The variation of **ΔT** against the „q" input experimental for al & brass, with velocity as a parameter. From fig. 4& 5, It is observed that increase of „q" input, increases the **ΔT**, as expected. With increase of velocity, **ΔT** decreases for the same „q" input. The brass fins should increases the surface temperature resulting in higher **‚ΔT'** for the same heat input (q input) & same velocity condition.

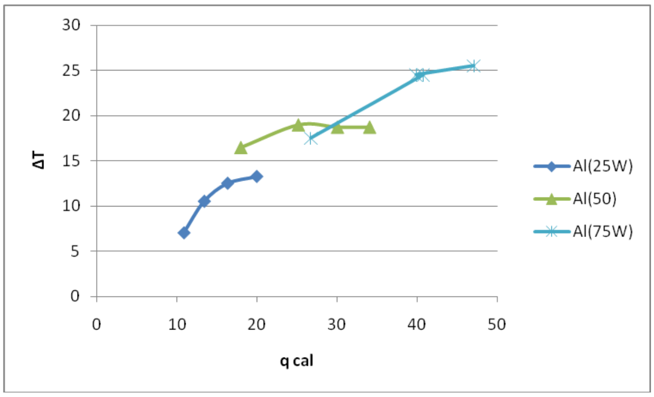


Figure 6: Total Heat transfer rate q vs Temperature difference ΔT for aluminium

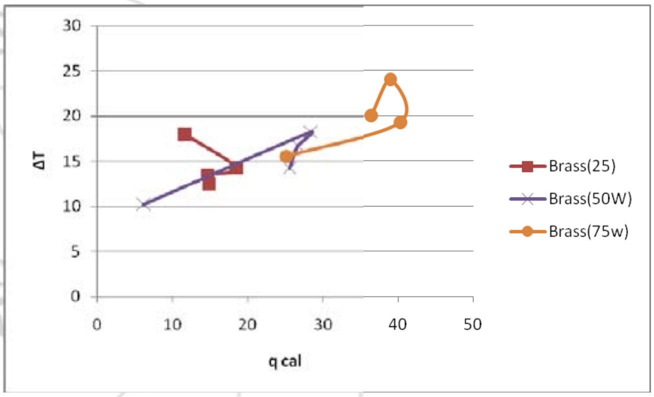


Figure 7: Total Heat transfer rate q vs Temperature difference ΔT for Brass

The characteristic of calculated total „q" value Vs **ΔT** . **ΔT** is based on observation & „q" total is calculated by using the correction for natural & forced convections. The radiations loss as worked out in specimen calculation.

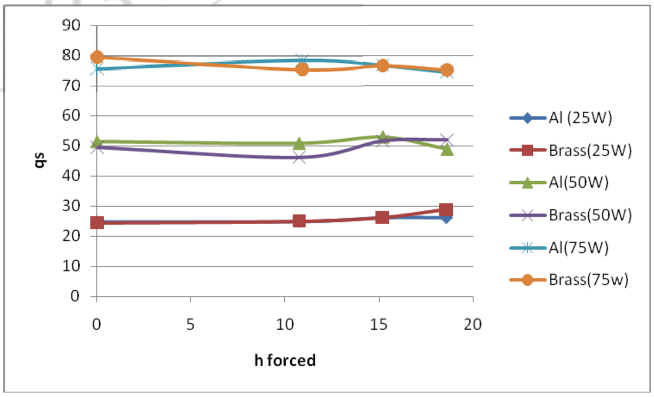


Figure 8: Forced heat transfer coefficient vs experimental heater input.

It is observed that, „h" forced increases with increase of heater input. With increase of velocity, heat transfer coefficient increases as expected. It is also observed that al fins gives higher values of heat transfer coefficient as expected for a few readings.

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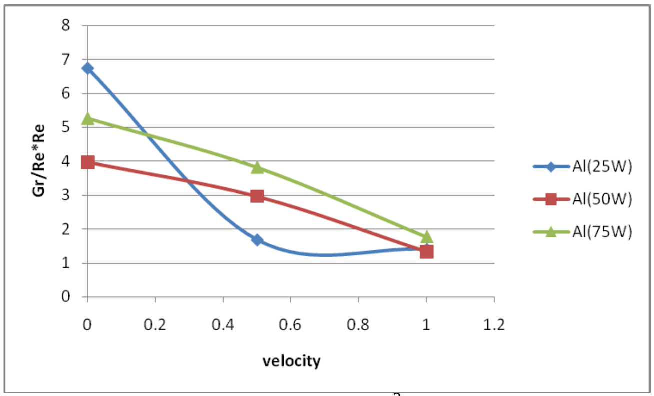

Figure 9: velocity vs Gr/Re^2 for aluminium

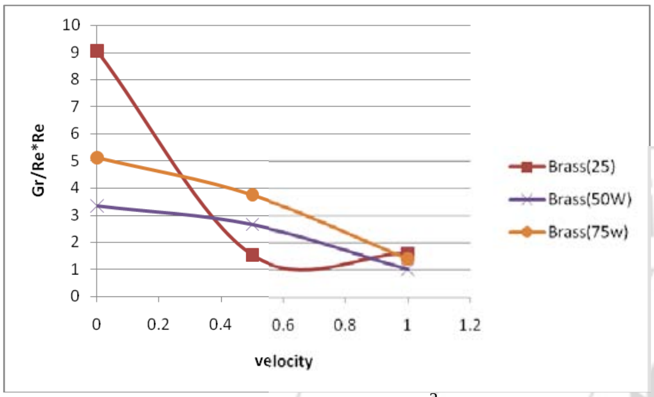

Figure 10: Velocity vs Gr/Re^2 for Brass

From fig.9 & 10 it is observed that the parameter Gr/Re^2 assumes the values of in the range from 1 to 10. With increase of velocity „Re‟ increases, resulting in the decrease of the parameter Gr/Re^2.

The combined convection region is that region, where both the convections are of similar magnitude the range of Gr/Re^2 from about 1 to 10 is a zone of combined convection.

4. Conclusions

From the experimental analysis of the set up, the following conclusion can be summarized:

1) The heat transfer coefficients for natural & forced condition are comparable with each other, indicating the combined convection region was present in the experiments.
2) The temperature of finned system decreases with increase in air velocity, as expected.
3) The specimen temperature are increasing in brass fins when compare with Al.
4) The observed value of Gr/Re2 within the prescribed zone i.e. 1 to 10 which is the combined convection effect.
5) From graph, it is clear that the value of heat transfer coefficient increases with increase in air velocity for given heat input.
6) It seen that value of Reynolds Number increases with increasing in air velocity.

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