

A Review on Experimental Study of Heat Transfer from Plate Fin in Mixed Convection Mode (Square, Elliptical and Circular Fin)

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Abstract: 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 applications. The selection of particular fin 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 fin profiles. Widely used fin profiles 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 results 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.

Keywords: Mixed convection mode, Pin fin array, Dimensional less number. Optimization.

1. Introduction

Heat transfer enhancement techniques (passive, active or a combination of passive and active methods) are commonly used in areas such as process industries, heating and cooling in evaporators, thermal power plants, air conditioning equipment's, refrigerator, for space vehicle, automobile etc. passive technique, where inserts are used in flow passage. To enhance the heat transfer rate, are advantageous compared with active techniques, because the insert manufacturing process is simple and this technique can be easily employed in existing heat exchanger. In compact heat exchanger design better result is observed by selecting proper passive insert configuration according to working condition of existing heat exchanger (both flow and heat transfer condition) In the past decades several techniques passive heat transfer augmentation techniques have been reported such as wire coils, ribs, fins, dimples etc.

Heat exchanger has several industrial and engineering applications. The design procedure of heat exchanger is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimation apart from issue such as long term performance and economic aspect of the equipment. The major challenge in designing a heat exchanger is to make the equipment compact and achieve a high heat transfer rate using minimum pumping power.

A number of practical situations 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.

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 ($0.3 \leq v \leq 3.0$) 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".

2. Literature Review

S. Rangadinesh, M. Rajasekar, S. Arunkumar and M. Venkatesan^[1] concluded that From the analysis carried out in this study, it can be inferred that the fabricated shoe brush-shaped fin maintains lower base plate temperature than the rectangular and cylindrical pin fins for the same exposed area, material properties and ambient conditions. Solution was run till the convergence criteria (10–5 for velocity and 10–6 for energy) were reached and temperature contours have been displayed for the various models for numerical studies. The numerical and experimental results were found to match reasonably well. Also, the fabricated fin maintains lower base temperature compared to the rectangular and cylindrical fins.

Shrikant Vasantrao Bhunte, Sanjay Kumbhare^[2] results in conclusion as follows with the change in metal foam material having different thermal conductivity leads to predict heat transfer behavior in the rectangular channel for various industrial applications. These results when relates with the previous investigation of different parameters of the fin, then it yield that PPI is the optimized parameter.

Sachindra Kumar Rout, Dipti Prasad Mishra, Dharendra Nath Thatoi, and Asit Ku^[3] Acharya concluded that The numerical investigation concentrates on wall temperature distribution of an internally finned tube for the case of laminar flow and their validation with existing analytical distribution, surface temperature distribution, and the surface heat transfer coefficient. The following conclusions can be reached from the present investigation. There exists an optimum fin number for which the heat transfer to the air is maximum and in the present case the optimum number of fin is found to be 10.

Ren-Tsung Huang, Wen-Junn Sheu, Chi-Chuan^[4] Wang the downward facing orientation yields the lowest heat transfer coefficient. However, the heat transfer coefficients for upward and sideward facing orientations are of comparable magnitude. It is found that the performance of sideward arrangement exhibits a greater dependence on fin structure.

Pardeep Singh, Harvinder lal, Baljit Singh Ubhi^[5] Fin with extensions provide near about 5 % to 13% more enhancement of heat transfer as compare to fin without extensions and concluded that Heat transfer through fin with rectangular extensions higher than that of fin with other types of extensions. Temperature at the end of fin with rectangular extensions is minimum as compare to fin with other types of extensions. The effectiveness of fin with rectangular extensions is greater than other extensions. Choosing the minimum value of ambient fluid temperature provide the greater heat transfer rate enhancement.

A.A.Walunj, D.D.Palande^[6] in his research found that natural convection heat transfer is depending on fin height and fin length as predicted. For selected fin spacing, the convection heat transfer rate increases with fin height and decreases with fin length. Convective heat transfer increases with aspect ratio but this behavior is different for different angle of inclination. Smaller fin length has no influence over heat dissipation through inclined base. Natural convection heat transfer increases monotonously with heat input and therein with temperature difference.

Sheng-Chung Tzeng and Tzer-Ming Jeng^[7] This study successfully used transient liquid crystal experimentation to measure the detailed heat transfer coefficient of end-wall in rectangular channel of linearly arrayed square pin array, the relative transverse spacing ($XT = ST = d$) was set as 3, and the relative longitudinal spacing ($XL = SL = d = 1:88-5$) and Reynolds number ($Re = 11047-17937$) were changed. Considering the end-wall area, the average Nusselt number with square pin was 1.46-2.58 times of that without square pin, and the square pin array of $XL = 3:75$ had the maximum end-wall heat transfer gain.

3. Theory of Combined Convection

Earlier we considered free convection resulting from unstable density gradients caused by the temperature gradients with the fluid.

We know from our examination of the dimensionless force of the governing equation that the relative magnitude of the dimensionless parameter (Gr/Re^2) governs. This dimensionless group can be expressed in terms of the physical parameter as,

$$\frac{G_r}{R_e^2} = \frac{gB(T_w - T_\infty)L}{U_0^2}$$

Which represents the ratio of the buoyancy forces to the inertia forces? When this ratio is of the order of unity that is $G_r \cong R_e^2$, the free & forced convection are of comparable magnitude & hence they should be analyzed simultaneously.

If $(Gr / Re^2) \gg 1$ For free convection / Natural convection dominates

$(Gr / Re^2) \ll 1$ Force convection

$(Gr / Re^2) \cong 1$ Combined convection

The heat transfer coefficient in case of combined convection is further influenced by relative direction of buoyancy force & externally applied force.

(1) Assisting / Aiding flow:

Here the direction of buoyancy force and externally applied force are same. Ex. Heated vertical plate with upward force motion.

(2) Opposing flow:

Here the direction of buoyancy force and externally applied force are opposite. Ex. Heated vertical plate with downward direction.

(3) Transverse flow:

Here the direction of buoyancy forces and the externally applied force are perpendicular to each other.

Ex. Horizontal flow over heated cylinder

The approximate correlation for combined convection can be obtained as-

$$N_u^n = Nu_f^n \pm Nu_N^n$$

Where, Nu_f = Nusselt number for forced convection

Nu_N = Nusselt number for natural convection

$n = 3$ (for aided and opposing flow)

Dimensionless Numbers

Reynolds Number

The Reynolds number is defined in terms of the properties of the fluid, characteristic Velocity, and hydraulic diameter.

Nusselt Number

The Nusselt number gives the ratio of actual heat transferred of the pin-fins array by the moving fluid to the equivalent heat transfer that would occur by conduction.

Advantages of Heat Transfer Enhancement

1. Improved fluid mixing
2. Enhance heat transfer
3. Fine-tuned size distribution
4. Enhanced mass transfer

Applications

1. In process industries especially in thermal
2. Heating and cooling in evaporator
3. Thermal power plant
4. In chemical process industries

5. A.C. equipment's
 6. Refrigerator
 7. Space vehicle
 8. Sugar factories.
 9. Natural and mixed convective waves generated by isolated thermal source are of interest in many practical problems such as positioning of heating elements in furnace and fire in enclosures and cooling of electronic circuitry.
 10. For normal operation of liquid metal of cooled fast breeder reactor (LMFBR) or a gas cooled faster breeder reactors (GCFBR), the coolant flow is in fully developed turbulent flow region and removal is determined by forced convection. However there are many transient conditions, under which coolant is at low rate and is influenced by buoyancy effect. For these conditions flow is in the laminar region and the heat removal is characterized by combined natural and forced convection.
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4. Conclusion

The mixed convection heat transfer changes as fin shape changes, and maximum heat transfer takes place in mixed convection mode. the change in material having different thermal conductivity leads to predict heat transfer behavior in the rectangular channel for various industrial applications. These results when relates with the previous investigation of different parameters of the fin, then it yield that mixed convection mode is the optimized parameter.

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