Experimental Analysis of Convective Heat Transfer Augmentation of Bi-Metallic Plate Heat Exchanger (A Review)

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Abstract - *Now a day's manufacturers of heat exchangers are continuously searching for new and optimized designs. The requirements of such designs are fulfil by using bi-metallic heat exchangers. This paper presents an attempt to collect information about the convective heat transfer coefficient and pressure drop of eight different combinations of bi-metallic plates with forced convection environment. The forced convective plate heat exchangers are usually used in thermal power plant, refrigeration and air-conditioning industry, milk pasteurizing plant and chemical process industry. Hence these industries use such system which provides better heat transfer with minimum pressure drop. To obtained optimized convective heat transfer coefficient and pressure drop various parameters related to the plate heat exchanger and heat input is taken into consideration. This article focused on detail review of work accomplished in technology of heat exchanger.*

Keywords: **Bi-metallic heat exchanger, Convective heat transfer coefficient, Forced convection, Pressure drop**

1. INTRODUCTION

Over the past few decades considerable attention has been devoted to heat transfer enhancement in thermal devices due to increased demands by industry for efficient and cost effective heat exchange equipment's. In this area, the passive methods are preferred over the active techniques. The former is more realistic and do not require extra power. A feasible approach to designing heat exchanger should also consider material usage and energy savings. Other design constraints are; the size of the device, its weight, and even its manufacturing simplicity. Improved technologies are frequently used in heat exchanging devices for the purpose of enhancing the heat transfer between a primary surface and the surrounding fluid. Various types of heat exchanger fins ranging from relatively simple shapes, such as rectangular, cylindrical, annular, tapered have been used. These fins may protrude from either a rectangular or cylindrical base. There are various parameters that characterize the fins, such as shape, number of plates, number of slots on plates, etc. The heat transfer and pressure drop characteristics of fin array systems have been the subject of extensive investigation because of its importance in a wide variety of engineering applications such as compact heat exchangers and the cooling of advanced gas turbine blades and electronic devices. The literature survey on the investigations of pin fin array systems indicates that these studies have examined the heat transfer and pressure drop characteristics and various parameters, such as inter fin spacing in both stream-wise direction and span-wise direction, gap clearance ratio, height to diameter ratios etc. However, the increase in heat transfer is always accompanied by a substantial increase in pressure loss. Therefore, in most applications of fins, both the heat transfer and pressure loss characteristics must be considered. Therefore, it is essential to investigate various plate fins with different number of slots over the plate surface, different number of plate fins with different heat input, in order to enhance the heat transfer and decrease the flow resistance. It is the aim of this study to investigate the heat transfer, pressure drop characteristics for the plate fins of copper material attached on a flat surface of aluminium surface in a rectangular duct.

List of Symbols

A_S	Heat transfer surface area
D_h	Channel hydraulic diameter
h_{av}	Average Convective heat transfer
Re	Reynolds number
T_S	Average Surface Temperature
T_{in}	Inlet temperature of Channel
T_{out}	Outlet temperature of Channel
ΔP	Pressure drop across the test section
Q_{elec}	Electrical heat transfer
Q_{cond}	Conduction heat loss
Q_{conv}	Convection heat loss
Q_{rad}	Radiation heat loss
U	Mean velocity of air
ν	Kinematics viscosity of air
W	Width of plate
L	Length of plate
ρ	Density of air
g	Acceleration due to gravity
H	Difference in manometer reading
T_m	Bulk mean temperature

2. LITERATURE REVIEW

M. Tahat *et. al.* [1] investigated experimentally steady-state heat-transfers from pin-fin arrays for staggered and in-line arrangements of the pin fins, which were orthogonal to the mean air flow. For the applied conditions, the optimal spacings of the fins in the span-wise and stream-wise directions have been determined. The dependences of the

Nusselt number upon the Reynolds number and pin-fin pitch in both directions have been obtained. These steady-state design data correlations obtained is to facilitate predicting the performances of aligned and staggered pin fins, when used as arrays in heat exchangers and hence optimal designs to be chosen.

N. Sahiti *et. al.* [2] performed heat transfer experiment in field of engineering research since increase in the effectiveness of heat exchangers through suitable heat transfer augmentation techniques can result in considerable technical advantages and savings of costs. Considerable enhancements were demonstrated by using small cylindrical pins on surfaces of heat exchangers. It uses simple relationships for the conductive and convective heat transfer to derive an equation that shows which parameters permit the achievement of heat transfer enhancements. Experiments are reported that demonstrate the effectiveness of the results of the proposed approach. Hence enhancement of heat transfer continues to be a challenging problem in different industrial fields. Therefore, an attempt to improve the performance of heat exchangers by using pin fins was undertaken. Here, properly distributed pins with an optimal height to diameter ratio will further substantially improve heat exchanger performance as pin fins are used.

Ahmet Ali Sertkaya *et. al.* [3] investigated experimentally natural convection heat transfer in air from a pin-finned surface by considering the effect of radiation heat transfer. The plate was oriented as the pin arrays facing either downwards or upwards from vertical axis with different angles and the experiments were performed for different values of heater power input. From the results of the experiments it is observed that the pin fins increase the heat transfer considerably when compared to the unpinned surface. The up facing pins are more enhancing heat transfer than the down facing pins and the enhancement is decreasing with increasing orientation angle from the vertical axis.

Henk Huisseune *et. al.* [4] studied the contribution of five different geometrical parameters to the thermal hydraulic performance of a compound heat exchanger with louvered fins and vortex generators. The air-side of a round-tube heat exchanger with louvered fins and delta winglet vortex generators were studied. The contribution of five important design parameters to the thermal hydraulic performance of the compound heat exchanger was numerically investigated. Knowing which parameters have the biggest influence is important for the optimization. To limit the number of simulations, the Taguchi method was used. At high inlet velocities the performance is mainly determined by the louvers, while at lower inlet velocities also the delta winglet geometry has a significant contribution. To validate the simulations, an aluminium compound heat exchanger was made and tested in a wind tunnel. This validation experiment showed that there is an acceptable match between the numerical results and measurements.

Kamil Arslan *et. al.* [5] studied steady-state forced convection heat transfer and pressure drop characteristics in a horizontal rectangular cross-sectioned duct, baffles mounted on the bottom surface with different inclination angles. Heat transfer and fluid friction for turbulent flow in a horizontal rectangular cross-sectioned duct with baffles on the bottom surface with different inclination angles were investigated experimentally with the Reynolds number ranging from 1×10^3 to 1×10^4 for Pr = 0.7. Dimensionless correlations are obtained for convection heat transfer and friction factor. The results of the present study are presented in terms of average Nusselt numbers and average Darcy friction factors. It was found that increase in the Reynolds number causes an increase in the average Nusselt number. On the other hand, it is also observed that average Darcy friction factor decreases with increasing Reynolds number.

Guoneng Li *et. al.* [6] carried out experiments to study the heat transfer performance of a heated circular cylinder in turbulent pulsating cross-flows. For a single heated circular cylinder, heat transfer enhancement factors up to 1.26 were observed in the studied parameter range. Two empirical correlations with different deviations were developed. The heat transfer enhancement factor was found to decrease with Strouhal number and Reynolds number, but increase in trend with the ratio of pulsating to steady Reynolds number.

Yidan Song *et. al.* [7] investigated a new generation of wavy-fin channels of a compact heat exchanger based on the constructal theory with maximizing the heat transfer rate and minimizing the pressure losses. Three dimensionless variables such as the channel space, the wavelength ratio and the amplitude ratio of two wavy walls are considered to find the optimal configuration of wavy-fin channels for the compact heat exchanger applied in a heat recovery system of a micro turbine. The results show that the new generation of wavy fin channel can help to reduce the pressure drop by more than 54% and to enhance the heat transfer rate by around 26%. The optimal design regions of the three dimensionless parameters are also provided so as to help design wavy-fin heat exchanger.

Supattarachai Suwannapan *et. al.* [8] presented an experimental and numerical study on thermal performance enhancement in a constant heat fluxed square duct inserted diagonally with 45° discrete V–finned tapes (DFT). The experiments were carried out by varying the air-flow rate through the tested square duct with DFT inserts for Reynolds number from 4000 to 25000. The effect of the DFT with V–tip pointing upstream at various relative fin heights and pitches on heat transfer and pressure drop characteristics was experimentally investigated. Both the heat transfer and pressure drop were presented in terms of Nusselt number and friction factor respectively. The DFT parameters mentioned above have a significant effect to the change of flow in duct leading to the increment of both the heat transfer rate and pressure drop. It is observed that the maximum of heat transfer and pressure drop from the DFT insert is found at the highest *R*B but at the lowest *R*P. For thermal performance comparison, the DFT at *R*P=1.5 and *R*B=0.1 yields the highest thermal enhancement factor of about 1.69 at the lowest *Re*. In numerical study, the DFT gives rise to two longitudinal counter rotating vortices along the duct that help to increase turbulence intensity. The mechanism of heat transfer enhancement is the impingement/reattachment flow of the longitudinal vortex flows.

Hae-Kyun Park *et. al.* [9] reported a joint experimental and numerical investigation of laminar forced convection heat transfer of a finned plate in a square duct. The heat transfer rates were measured for fixed fin heights, fin thicknesses, and base-plate geometries, with systematically varied fin spacing, tip clearance, Prandtl number and Reynolds number. The optimal tip clearances were identified, which maximized the total heat transfer. The total heat transfer rate at the optimal tip clearance was maximum 33% higher than that at the largest tip clearance. It decreased as the Prandtl number increased and as the Reynolds number increased. The dependence of the heat transfer rate on the tip clearance weakened as the fin spacing increased.

Jung Shin Park *et.al.* [10] investigated experimentally heat transfer and pressure drop in a duct with three serial perforated blockages equipped with staggered jets. Eight types of jet holes and three types of side walls, including dimpled walls, were tested. For heat transfer measurements, the transient liquid crystal technique was used. Reynolds numbers based on the hydraulic diameter of the duct and inlet velocity ranged from about10000–30000. Experimental results showed that the Nusselt number ratios decreased as the Reynolds number increased, and the friction factor ratios increased as the Reynolds number increased. The heat transfer coefficient and the pressure loss were strongly affected by the number and the configuration of jets. Compared to the smooth side wall case, the cases with dimpled side walls showed large increases in heat transfer with slight increments in pressure loss. Therefore, it was determined that the thermal performance factor could be enhanced by up to 25% by using a dimpled side wall in the duct with perforated blockages.

R. Sajedi *et. al.* [11] presented a numerical analysis for studying effect of splitter on the hydro thermal behaviour of a pin fin heat sink. The concept of application of pins in the heat sinks arises from increasing the heat transfer area to reach maximum rate of heat losses in a limited space. On the other hand, flow separation behind the pin will enhance the pressure drop. To avoid or weaken the flow separation and reduce the pressure drop through the heat sink, a thin plate is located on the back of the pin. Two common pin fin heat sinks with circular and square pin shapes are compared together with and without splitters. Results showed that the use of splitter improves the hydro-thermal performance of both circular and square pins, so that the maximum improvement will be occurred for the case of Q = 10 W and V = 4.5 m/s.

R. K. Ali [12] investigated experimentally the effect of rectangular winglet vortex generators on thermal performance of square flat heat source near a wake region. Rectangular winglets were fixed on the base board with common inflow orientation to direct the flow toward the core of stagnation zone. The proposed configuration causes significant flow acceleration that enhances heat transfer from near-wake heat source surfaces besides the generated large-scale turbulence vortices. The effect span-wise and downstream distances, size, number and attack angle of vortex generator on the heat transfer rate and pressure drop were investigated in turbulent flow. This investigation showed that the applications of vortices generators in cooling of heat dissipation elements as an enhancement technique is promise, but deeper understanding of flow structure and optimizing vortex generator size for specific location and orientation is needed

3. DATA PROCESSING

The data obtained from experiments are processed for further analysis with the help of various formulae. The convective heat transfer rate Q_{conv} from electrically heated test surface is calculated by following formula:

$$Q_{conv} = Q_{elect} - Q_{cond} - Q_{rad} \qquad (1)$$

Where, Q indicates the rate of heat transfer in which subscripts conv, elect, cond and rad denote convection, electrical, conduction and radiation, respectively. The electrical heat input is obtained from the electrical voltage and current supplied to the surface. In similar studies, investigators [1, 5] reported that total radiative heat loss from a similar test surface would be about 0.5% of the total electrical heat input. The conductive heat losses through the sidewalls can be neglected in comparison to those through the bottom surface of the test section. Using these findings together with the fact that the two sidewalls and the top wall of the test section is well insulated therefore one could assume with some confidence that the last two terms of Eq. (1) may be ignored. The heat transfer from test section by convection can be evaluated as:

$$Q_{conv} = h_{av} A_s [T_s - (\frac{T_{out} + T_{in}}{2})] \qquad (2)$$

Hence, the average convective heat transfer coefficient can be expressed as:

$$h_{av} = \frac{Q_{conv}}{A_s [T_s - (\frac{T_{out} + T_{in}}{2})} \qquad (3)$$

Either the projected or the total area of the test section can be treated as the heat transfer area in the calculations. The projected area is considered for present investigation for calculation of heat transfer coefficient. The projected area is calculated by using following formula:

$$Projected\ area = W \times L \qquad (4)$$

The dimensionles groups are calculated as follows

Reynolds Number: It is ratio of inertia force to viscous force. It is computed by using the equation:

$$Re = \frac{D_h U}{v} \quad (5)$$

Pressure Drop: It is defined as the difference in total pressure between two points of a fluid carrying network. Pressure drop occurs when frictional forces, caused by the resistance to flow, act on a fluid as it flows through the tube or duct. The pressure drop can be calculated as follows:

$$\Delta P = \rho g H \quad (6)$$

In all calculations, the values of thermo-physical properties of air were obtained at the bulk mean temperature, which is

$$T_m = \frac{T_{in} + T_{out}}{2} \quad (7)$$

The system of bi-metallic plate heat exchanger will be tested under forced convection for different combinations of number of plates with different number of slots over the plates. The number of sets of experiment obtained by using factorial design of experiment and evaluation of response variable will be done by using above equations. Further analysis for maximum convective heat transfer coefficient and minimum pressure drop and optimization will be done by using analysis of variance techniques.

4. CONCLUSIONS

Heat transfer augmentation is prime important issue in process industries. It is challenging issue to design and development of heat exchanger equipments which dissipates maximum amount of heat with reducing weight as well as cost of heat exchanger. The latest techniques of fabrication of heat exchangers are required to modernize of heat exchanger to exchange maximum amount of heat between protruded surfaces and ambient medium. When bi-metallic plates are used for heat exchangers which resulted into higher heat transfer rate due to higher contact area and maximum thermal conductivity with optimize cost. Also the uses of plates with various slots over the surface are reduces the remarkable weight of heat exchanger and this is economical benefit with more enhancement heat transfer rate because of increase of heat transfer area due to the slots.

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