HEAT TRANSFER ENHANCEMENT IN FIN AND TUBE HEAT EXCHANGER - A REVIEW

Praful Date[1] and V. W. Khond[2]
[1]M. Tech. Heat Power Engineering, G.H Raisoni College of Engineering, Nagpur, Maharashtra, India
[2]Department of Mechanical Engineering, G.H Raisoni College of Engineering, Nagpur, Maharashtra, India
E-Mail: praful.date@gmail.com

ABSTRACT

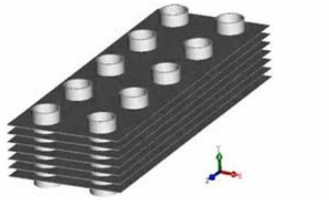
This paper proposed the novel approached toward the heat transfer enhancement of plate and fin heat exchanger using improved fin design facilitating the vortex generation. The vortex generator can be embedded in the plane fin and that too in a low cost with effect the original design and setup of the commonly used heat exchangers. The various design modifications which are implemented and studied numerically and experimentally is been discussed in the paper.

Keywords: heat transfer enhancement, fin tube heat exchanger, vortex generation.

INTRODUCTION

Heat exchangers have been widely used in the fields of refrigeration, air conditioning, space heating and chemical engineering. Fin-tube heat exchanger with two rows of round tubes is widely used in air-conditioning and refrigeration systems to meet such demands as fan power saving and quietness. Traditional heat exchanger devices such as plate type, plate fin type and tubular type operate on the principle of temperature difference between two mediums and can realize efficient sensible heat transfer from one fluid to another. With the development of design of heat exchanger and making some changes without affecting the cost much the heat transfer enhancement can be achieved. One such novel approach is using punched winglet-type vortex generator in fin tube heat exchanger which is proved numerically that it enhance the heat transfer.

Y.L. He *et al*., [1] proposed the numerical analysis of heat-transfer enhancement by punched winglet type vortex generator arrays in fin and tube heat exchanger. The potential of punched winglet type vortex generator arrays is use to enhance air side heat transfer performance of finned tube heat exchanger. The array is composed of two delta winglet pairs with two layout modes of continuous and discontinuous winglets. For the punched Vortex generator cases, the effectiveness of the main vortex to the heat transfer enhancement is not fully dominant while the "corner vortex" also shows significant effect on the heat transfer performance. Two kinds of VG arrays and a conventional VG configuration in common flow up arrangement are performed in this numerical study. The designs parameters such as punching effects, attack angle and placement locations of delta winglet on the flow and heat transfer characteristics were examined. The schematic shown in Figure-1 is a core diagram of plane fin tube heat exchanger with two row tubes along with the flow direction of fluid.



(a) Schematic of core region of a plain fin-and-tube heat exchanger

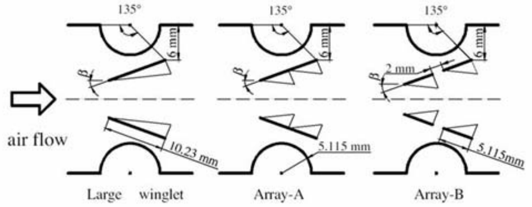


Figure-1. [1]

The tube outside diameter *Dc* is 10.23mm, the transverse tube pitch *Pt* is 25.4mm, the longitudinal tube pitch *Pl* is 22mm, the fin pitch *Ft* is 3.2mm and the fin thickness is 0.13mm.

Considering the large winglet design, first the delta winglet pairs are punched out from the fin surface and place symmetrically on both sides of each round tube in an inline arrangement. The base chord length *l and* height *h* of large winglet are 10.23mm and 2.56mm, respectively. The tube outside diameter *Dc* is 10.23mm, the transverse tube pitch *Pt* is 25.4mm, the longitudinal tube pitch *Pt* is 22mm, the fin pitch *Fp* is 3.2mm, and fin thickness *Tf* is 0.13mm.

Mao Yu Wen and Ching Yen Ho [2] present the information of an experimental design on the elements of the fin and tube heat exchanger. In this study the three different types of the fin design were proposed (plate fin, wavy fin, and compounded fin) and investigated. The heat transfer coefficient, the pressure drop of the air side, the Colburn factor (j), and fanning friction factor (f) against air velocity (1-3 m/s) and Reynolds number (600-2000) have been discussed in this paper.

Air was driven by a 1.0 HP frequency adjusted axial blower from a wind tunnel within a test section. The test section was constructed by using a commercial plexiglass plate, 5 mm thick. The dimension of the test section was 270 mm (width), 270 mm (height) and 850 mm (length). The heat source was supplied by a hot water thermostat reservoir. The experimental sketch is shown in below Figure-2.

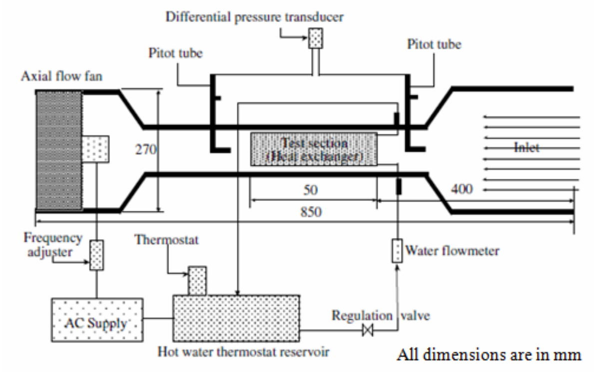


Figure-2. [2]

The three types of the fin design which are proposed and tested in this paper are shown in the below Figure-3.

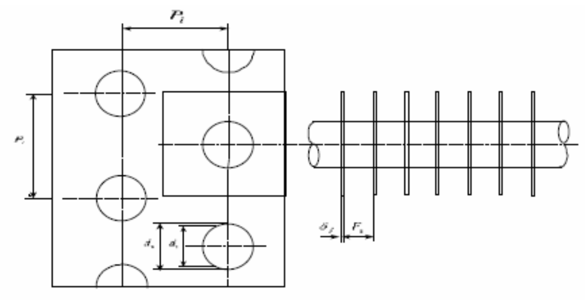
(a) plate fin

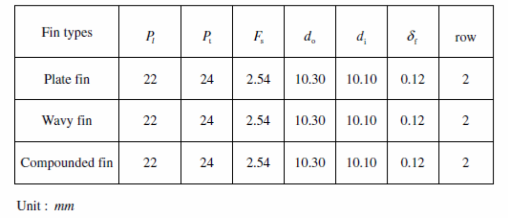
(b) wavy fin

(c) compounded fin

Figure-3. [2]

The best configuration for the three types of the fin designs is also presented in this paper as given below with nomenclature and diagram.





Fin types	P_l	P_t	F_s	d_o	d_i	δ_f	row
Plate fin	22	24	2.54	10.30	10.10	0.12	2
Wavy fin	22	24	2.54	10.30	10.10	0.12	2
Compounded fin	22	24	2.54	10.30	10.10	0.12	2

Unit : *mm*

Figure-4. [2]

A. Joardar and A. M. Jacobi [3] experimentally investigated the winglet type vortex generator arrays for air side heat transfer in a full scale wind tunnel. In this study the effect of the 3 vortex generator tube inline array was compared to a single row vortex generator design and the base line configuration. Particular vortex generator configuration called common up flow has been shown effective in delaying the boundary layer separation from the tube. Common up flow configuration for tube wake management is implemented and the use of winglet arrays is explored and compared to leading edge vortex generator with experimental setup as show in Figure-5.

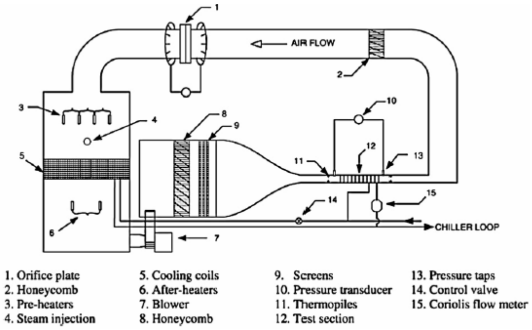


Figure-5. [3]

The heat exchanger proposed in this paper is 7 rows and 4 column fin and plate type. Figure-6 (a) and Figure-6 (b) shows the design details of the fin and plate heat exchanger.

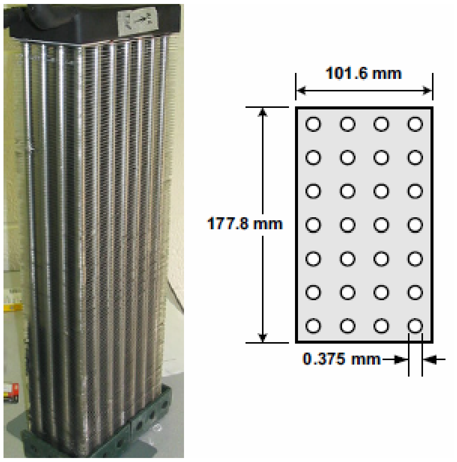


Figure-6 (a). [3]

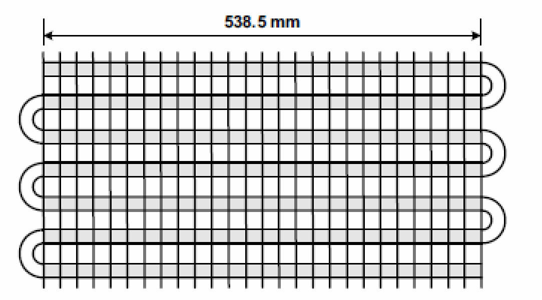


Figure-6 (b). [3]

The vortex generator again proposed in this paper is of winglet type but with advance arrangement as shown in Figure-7 and Figure-8(a) and (b).

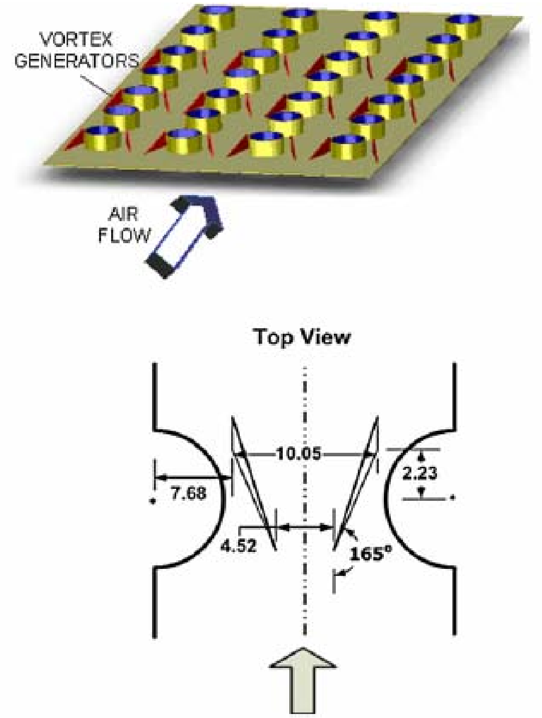


Figure-7. [3]

Figure-8(a). [3]

Figure-8(b). [3]

Jiong Li *et al*., [4] proposed the numerical analysis of a slit fin and tube heat exchanger with longitudinal vortex generator. A 3D numerical simulation is performed on laminar heat transfer and flow characteristics of a slit fin and tube heat exchanger with longitudinal vortex generator. Heat transfer enhancement of novel slit fin mechanism is investigated by examining the effects of strips and the longitudinal vortices. Slit fins are same like some pieces of strips are punched from the fin sheet. Figure-9 shows the fin design which was proposed and investigated numerically in this paper.

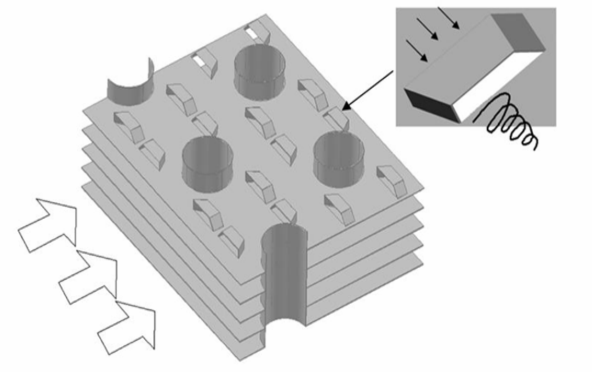


Figure-9. [4]

J.H. Doo *et al*., [5] proposed the theoretical prediction of longitudinal heat conduction effect in cross corrugated heat exchanger. In elementary heat exchanger design theory the longitudinal heat conduction through the heat transfer plate separating cold and hot fluid stream is neglected, and only the transverse heat conduction is taken into account for the conjugate heat transfer problem. Figure-10 shows the design configuration presented in this paper which is a cross flow heat exchanger method.

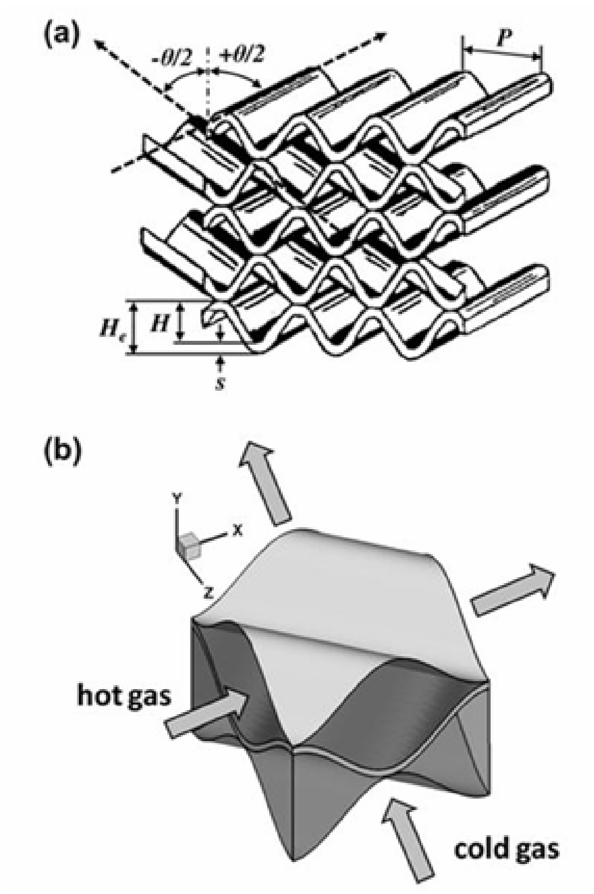


Figure-10. [5]

Y. Chen *et al*., [6] investigated the effect of punched longitudinal vortex generator in form of winglets staggered arrangements to enhance the heat transfer in high performance finned oval tube heat exchanger. Winglets in staggered arrangement bring larger heat transfer enhancement than in inline arrangement. K. Torii *et al*., propose a novel technique that can augment heat transfer but nevertheless can reduce pressure-loss in a fin-tube heat exchanger with circular tubes. The winglets are placed with a heretofore-unused orientation for the purpose of augmentation of heat transfer. This orientation is called as ‘‘common flow up’’ configuration. The proposed configuration causes significant separation delay, reduces form drag, and removes the zone of poor heat transfer from the near-wake of the tubes. Jin-Sheng Leu *et al*., numerically and experimentally analyses the heat transfer and flow in the plate-fin and tube heat exchangers with inclined block shape vortex generators mounted behind the tubes. The results indicated that the proposed heat transfer enhancement technique is able to generate longitudinal vortices and to improve the heat transfer performance in the wake regions.

K. Torii *et al*., [7] proposes a novel technique that can augment heat transfer but nevertheless can reduce pressure-loss in a fin-tube heat exchanger with circular tubes in a relatively low Reynolds number flow, by deploying delta winglet-type vortex generators. Following the same arrangement as discussed in many papers above, “common flow up” configuration as well as the “common flow down” configuration is shown with the diagram as shown in Figure-11(a) and (b).

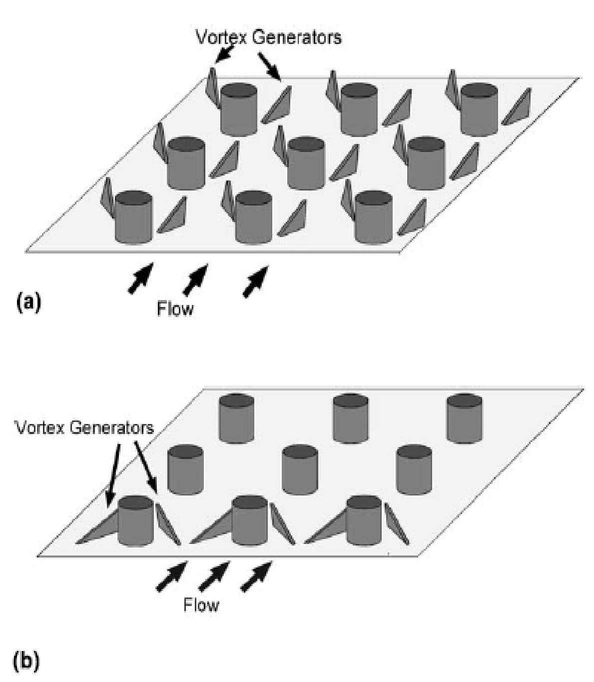


Figure-11. [7]

Jin-Sheng Leu *et al*., [8] numerically and experimental analyses were carried out to study the heat transfer and flow in the plate-fin and tube heat exchangers with inclined block shape vortex generators mounted behind the tubes. The effects of different span angles are investigated in detail for the Reynolds number ranging from 400 to 3000.

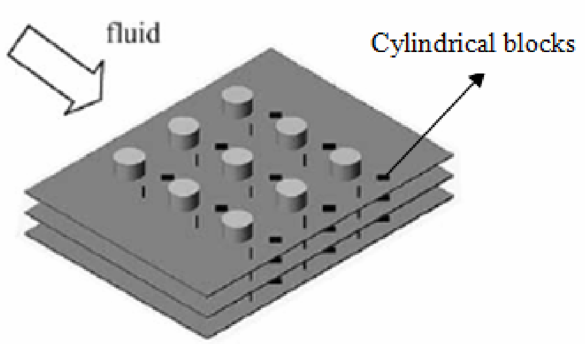


Figure-12. [8]

Figure-12. Shows the typical arrangement of the vortex generator and its design configuration.

J.M. Wu and W.Q. Tao [9] achieve heat transfer enhancement and lower pressure loss penalty, even reduction in pressure loss; two novel fin-tube surfaces with two rows of tubes in different diameters are presented in this paper. Numerical simulation results show that the fin-tube surface with first row tube in smaller size and second row tube in larger size can lead to an increase of heat transfer and decrease of pressure drop in comparison with the traditional fin-tube surface with two rows of tubes in the same size. Figure-13(a) and (b) shows the design parameters analyzed and test in this paper.

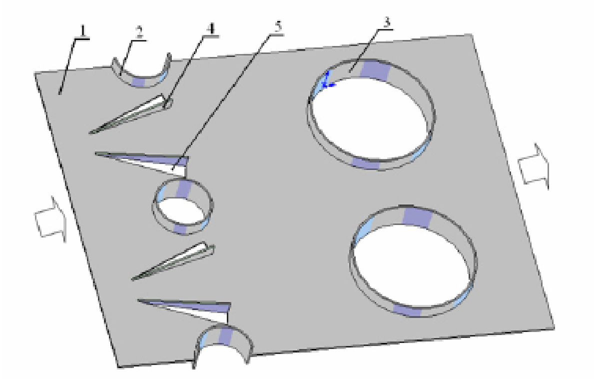


Figure-13 (a). Punched delta winglet pairs in “common flow up” orientation [9].

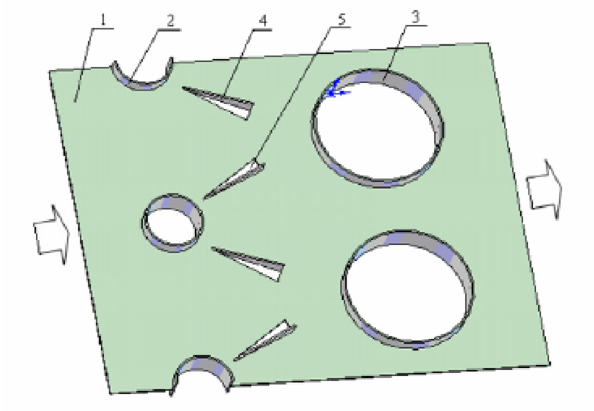


Figure-13 (b). Punched delta winglet pairs in “common flow down” orientation [9].

1. Fin 2. Smaller tube 3. Larger tube 4. Delta winglet 5. Punched hole.

CONCLUSIONS

Various type of possible and cost effective technique of the heat transfer enhancement were presented in this literature review. It is clear the vortex generator technique is one of the promising approaches of heat transfer enhancement. Lot of work been carried out on various designs and use of simulation software made it easier.

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