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Experimental Study of Heat Transfer Enhancement in Fin Tube Heat Exchanger by Vortex Generator-A Review

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Abstract

This review paper presents the work of various researchers on the heat transfer enhancement of fin tube heat exchanger. In this research author used different type of vortex generator like delta winglet, rectangular winglet, curved trapezoidal winglet pair. The vortex generator can be embedded in the plate 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 exchanger, heat transfer enhancement, fin tube heat exchanger, vortex generation..

Introduction

Heat exchangers have been widely used in the fields of refrigeration, air conditioning, water cooler, space heating, automobile and chemical engineering. Fin-tube heat exchanger with two rows of round tubes is widely used in air-conditioning and refrigeration systems. Traditional heat exchanger devices such as plate type, plate fin 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.

Literature Review

S.M. Pesteei et al. [1]

This paper present local heat transfer coefficients were measured on fin-tube heat exchanger with winglets using a single heater of 2 inch diameter and five different positions of winglet type vortex generators. The measurements were made at Reynolds number about 2250. Flow losses were determined by measuring the static pressure drop in the system. Results showed a substantial increase in the heat transfer with winglet type vortex generators. It has been observed that average Nusselt number increases by about 46% while the local heat transfer coefficient improves by several times as compared to plain fin-tube heat exchanger. The maximum improvement is observed in the re-circulation zone. The best location of the winglets was with DX = 0.5D and DY = 0.5D. The increase in pressure drop for the existing situation was of the order of 18%.

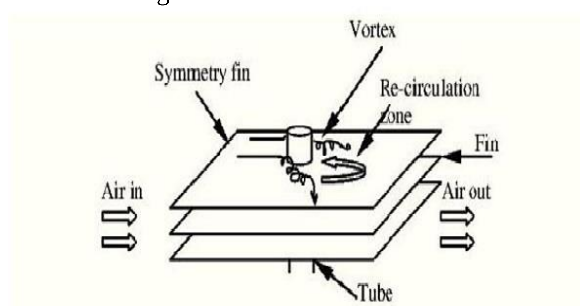

Figure-1.Fin tube configuration and flow characteristics

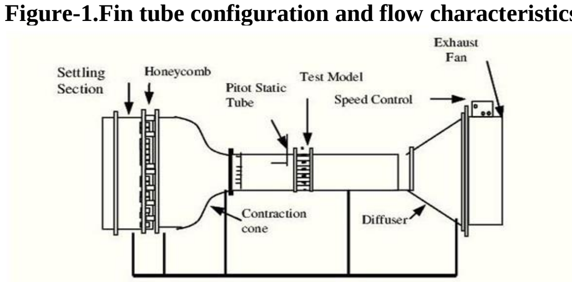

Figure-2. Schematic of the wind tunnel

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Ya-Ling He et al. [2]

Investigated the heat transfer enhancement and pressure loss penalty for fin-and-tube heat exchangers with rectangular winglet pairs (RWPs) were numerically investigated in a relatively low Reynolds number flow. The purpose of this study was to explore the fundamental mechanism between the local flow structure and the heat transfer augmentation. The RWPs were placed with a special orientation for the purpose of enhancement of heat transfer. The numerical study involved three-dimensional flow and conjugate heat transfer in the computational domain, which was set up to model the entire flow channel in the air flow direction. The effects of attack angle of RWPs, row-number of RWPs and placement of RWPs on the heat transfer characteristics and flow structure were examined in detail. It was observed that the longitudinal vortices caused by RWPs and the impingement of RWPs-directed flow on the downstream tube were important reasons of heat transfer enhancement for fin-and-tube heat exchangers with RWPs. It was interesting to find that the pressure loss penalty of the fin-and-tube heat exchangers with RWPs can be reduced by altering the placement of the same number of RWPs from inline array to staggered array without reducing the heat transfer enhancement. The results showed that the rectangular winglet pairs (RWPs) can significantly improve the heat transfer performance of the finand- tube heat exchangers with a moderate pressure loss penalty.

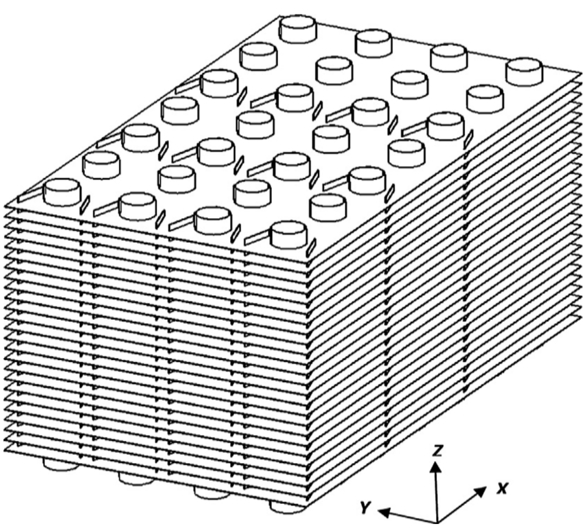

Figure-3. Schematic diagram of core region of a fin-and-tube heat exchanger with RWPs.

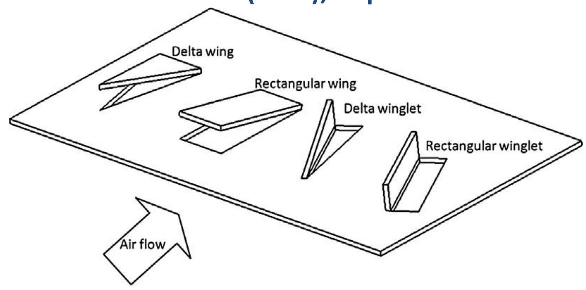

Figure-4. Four basic vortex generator forms.

They found that the rectangular winglet pairs (RWPs) is one promising heat transfer enhancement technique. The RWP sgenerated vortices can enhance the thermal mixing of the fluid, delay the boundary layer separation, and reduce the size of tube wake. The longitudinal vortices generated by RWPs rearrange the temperature distribution and the flow field, and as a consequence significantly enhance the heat transfer performance of the fin-and-tube heat exchanger. Due to the "common-flow-up" orientation of the RWPs, a constricted nozzle-like passage is created between the RWPs and the aft region of the tube and hence the fluid is accelerated in this region. The accelerated flow cannot only further delay the boundary layer separation and reduce the tube wake, but also impinge directly on the downstream tube, which resulting in significant augmentation of local heat transfer.

The staggered-RWPs array in the fin-and-tube heat exchangers can augment the heat transfer as good as the inline-RWPs array. In addition, compared with the inline-RWPs array, the staggered-RWPs array can further reduce the pressure loss penalty due to the asymmetric arrangement of the vortex generators. It is expected that the staggered-RWPs array can further reduce the pressure loss penalty with increase of the Reynolds number.

C.B. Allison et al. [3],

Investigated the experimental analysis of the effects of delta-winglet vortex generators on the performance of a fin and tube radiator is presented. The winglets were arranged in flow-up configuration, and placed directly upstream of the tube. This is a hitherto untested configuration, but is thought to have certain advantages. In addition to vortex generation the flow is guided onto the tube surface increasing the localised velocity gradients and Nusselt numbers in this region. The study includes dye visualisation and full scale heat transfer performance measurements. The results are compared to a standard louvre fin surface. It was found that the

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winglet surface had 87% of the heat transfer capacity but only 53% of the pressure drop of the louvre fin surface.

They found that the heat transfer mechanisms of the two fin surfaces differ dramatically. The louver fin surface facilitates boundary layer renewal and has numerous leading edges. The delta-winglet fin has fewer leading edges and relies predominantly on increasing convection through vortex generation. According to the results, the louver fin is superior to the deltawinglet fin. Although coherent vortices were generated from the first row of winglets, we doubt wether the downstream winglets produce the same level of vorticity. This implies that only the first row of winglets may be effective in producing vortices which can improve heat transfer.

M.C. Gentry et al. [4]

Investigated the heat transfer enhancement by various vortex generators mounted at the leading edge of a flat plate. They demonstrated a 50– 60% improvement in average heat transfer over the surface of the plate, using delta-wing vortex generators. It is worth noting that a delta-wing is like an isosceles triangle mounted symmetrically to the flow, and the angle of attack is measured between the plate and the lean of the delta. A delta-winglet on the other hand is like a right-angled triangle (or half delta) mounted perpendicular to the plate, but at an incident angle measured parallel to the inlet flow. Gentry and Jacobi varied the angle of attack from 25º to 55º, with the optimum enhancement occurring at an angle of attack of 40º.

Y.L. He et al. [5],

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.

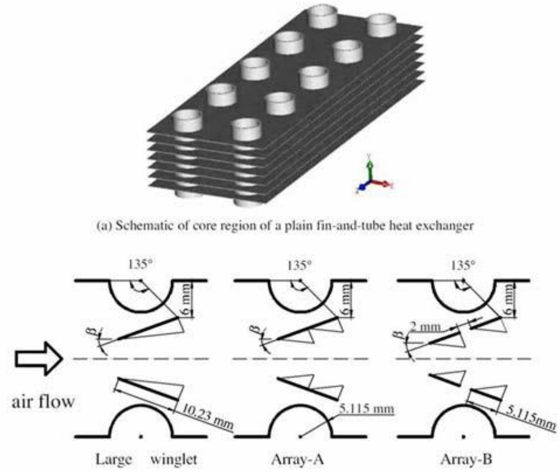

Figure-5. [5]

Mao Yu Wen et al. [6]

Presented 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-6.

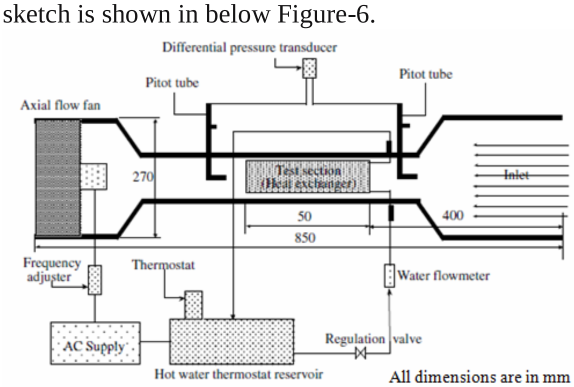

Figure-6. [6]

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

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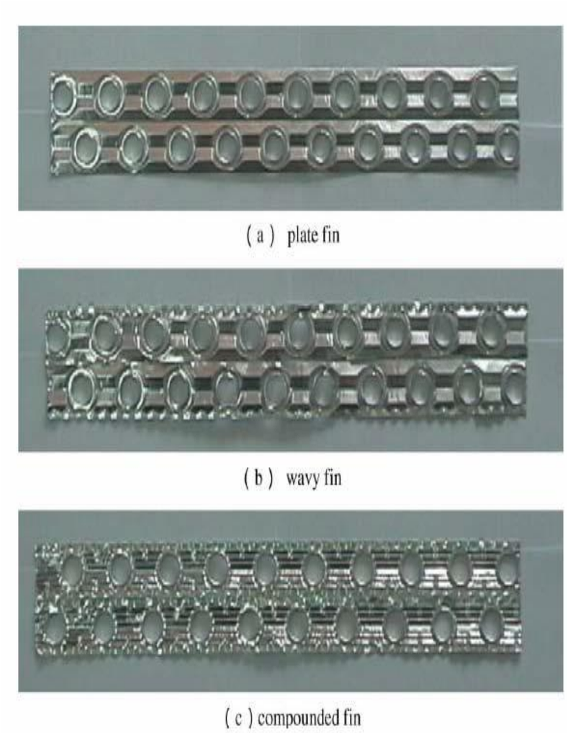

Figure-7. [6]

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

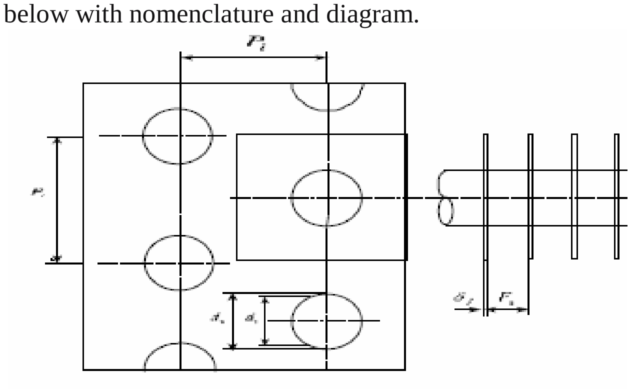

Figure-8.[6]

Jiong Li et al. [7],

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.

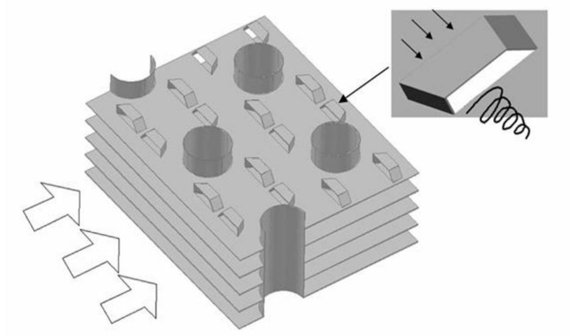

Figure-9. [7]

Henk Huisseune,Christophe T'Joen, Peter De Jaeger, Bernd Ameel, Sven De Schampheleire, Michel De Paepe[8]

Louvered fin and round tube heat exchangers are widely used in air conditioning devices and heat pumps. In this study the effect of punching delta winglet vortex generators into the louvered fin surface in the near wake region of each tube was numerically investigated using computational fluid dynamics (CFD). The delta winglets serve to reduce the size of the tube wakes. They cause three important mechanisms of heat transfer enhancement. First, due to the swirling motion of the generated vortices, hot air is removed from the tube wake to the mainstream regions and vice versa. Second, the induced wall-normal flow locally thins the boundary layer, which also enhances the heat transfer. Third, the size of the wake zones is reduced because the flow separation from the tube surface is delayed. This also results in a reduced form drag of the tube surface. The net core pressure drop, however, increases when adding delta winglets to the louvered fins because of increased friction and flow blockage. For the same heat duty and pumping power, the louvered fin heat exchanger with delta winglets is more compact than when no delta winglets are present.

Y. Chen et al. [9],

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 fintube heat exchanger with circular tubes. The winglets are placed with a

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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. [10]

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-10(a) and (b).

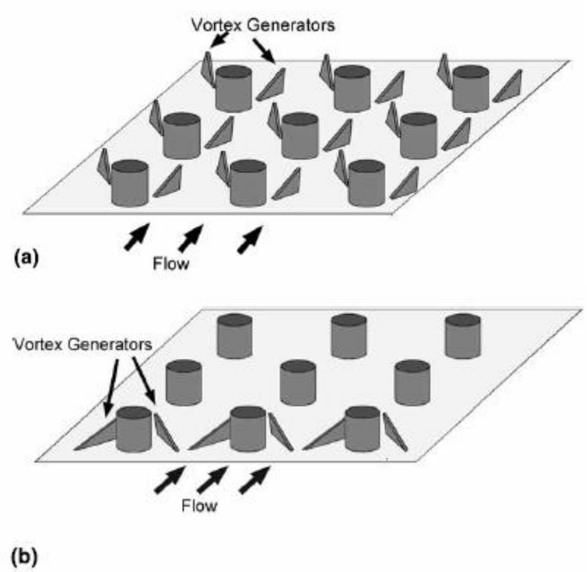

Figure-10. [10]

Jin-Sheng Leu et al. [11]

Numerical 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.

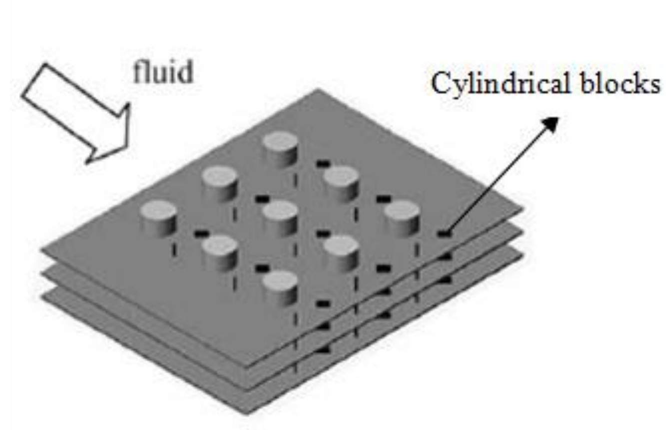

Figure-11. [11]
Figure-11. Shows the typical arrangement of the vortex generator and its design configuration

J.M. Wua et al. [12]

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-12(a) and (b) shows the design parameters analyzed and test in this paper

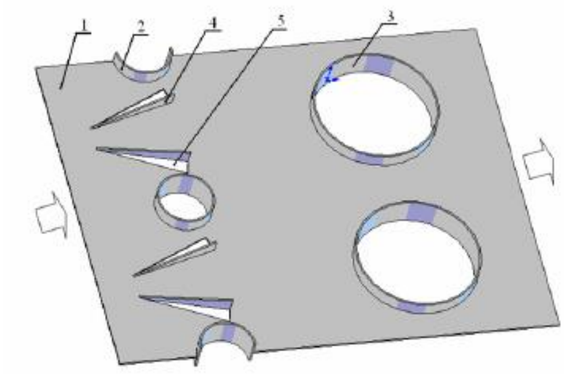

Figure-12 (a). Punched delta winglet pairs in “common flow up” orientation [12].

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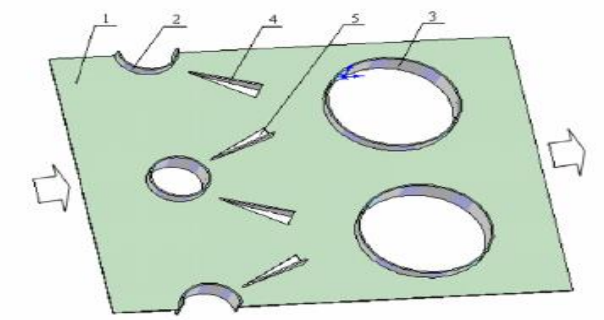

Figure-12 (b). Punched delta winglet pairs in "common flow down" orientation

Guobing Zhou et al. [13]

The performance of a pair of new vortex generators e curved trapezoidal winglet (CTW) has been experimentally investigated and compared with traditional vortex generators e rectangular winglet, trapezoidal winglet and delta winglet using dimensionless factors e j/j0, f/f0 and R ¼ (j/j0)/(f/f0). The results showed that delta winglet pair is the best in laminar and transitional flow region, while curved trapezoidal winglet pair (CTWP) has the best thermohydraulic performance in fully turbulent region due to the streamlined configuration and then the low pressure drop, which indicates the advantages of using this kind of vortex generators for heat transfer enhancement. Parametric study on CTWP showed that smaller attack angle (b ¼ 0_ ¼ and 15_), larger curvature (b/a ¼ 1/2) and larger angle of inclination (a ¼ 20_) gives better thermohydraulic performance under the present conditions. An appropriate spacing between the leading edges of a pair of CTW VG should be considered for different flow regions. In addition, double rows of CTWP do not show better thermohydraulic performance due to the larger pressure drop and the spacing between the two rows of CTWP should also be optimized.

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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