OPEN ACCESS
ISSN: 2249-6645

International
Journal
Of Modern Engineering Research (IJMER)

Study of Flow & Heat Transfer in Plate Fin Heat Exchanger at Varying Reynold's Number

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ABSTRACT: *Heat transfer characteristics and flow structure in laminar and turbulent flows through a rectangular channel containing built in vortex generators have been analyzed by means of solutions of the full Navier-Stokes and energy equations The effects of two different shaped LVGs, rectangular winglet pair (RWP) and delta winglet pair (DWP) with two different configurations, common -flow-down (CFD) and common-flow-up (CFU), are studied. The numerical results indicate that the application of LVGs effectively enhances heat transfer of the channel. According to the performance evaluation parameter,* $(Nu/Nu_0)/(f/f_0)$*, the channel with DWP has better overall performance than RWP; the CFD and CFU configurations of DWP have almost the same overall performance; the CFD configuration has a better ove rall performance than the CFU configuration fo r RWP. The basic mechanism of heat transfer enhancement by LVGs can be well described by the field syner gy principle. The main purpose of this study is to show the performance of delta winglet type vortex generators in improving heat transfer.*

Keywords: *Vortex generator; Common flow up; Heat transfer en hancement; Plate-fin& tube heat exchanger*

I. INTRODUCTION

The thermal performance of refrigerant-to-air heat exchangers is often described in terms of thermal resistances and a reduced thermal resistance implies improved heat exchanger performance. The total thermal resistance of a refrigerant to air heat exchanger is the sum of three resistances: the air-side convective resistance, the wall conductive resistance, and refrigerant side convective resistance. However,these three resistances do not contribute equally to the total thermal resistance of the heat exchanger. The air side resistance is generally much higher than the other contributions. The air-side thermal resistance accounts for 76 percent of the total evaporator resistance and 95 percent of the total condenser resistance in the two-phase regions of residential refrigerator heat exchangers. Efforts to improve refrigerant to air heat exchanger performance should focus on reducing the dominant thermal resistance on the air side of the heat exchanger generators usually are incorporated into a surface by means of embossing, stamping, punching, or attachment process. They generate longitudinal vortices which swirl the primary flow and increase the mixing of downstream regions. In addition, the vortex generator determines

the secondary flow pattern. Thus, heat transfer enhan cement is associated with the secondary flow with relativel y low penalty of pressure drop A modified rectangular longitudinal vortex generator obtained by cutting off the four corners of a rectangular wing is presented. Fluid flow and heat transfer characteristics of longitudinal vortex generator mounted in rectangular channel are experimentally investigated and compared with those of original rectangular longitudinal vortex generator. Results show that the modified rectangular wing pairs have better flow and heat transfer characteristics than those of rectangular wing pair. The literature reporting the enhancement of heat transfer of using surface protrusion vortex generators. They noted a maximum in-crease in the local Nusselt number of 40%.conducted heat transfer measurement for a single longitudinal vortex embedded in a turbulent boundary layer. They interpreted their data in terms of vortex circulation and boundary layer thickness extended this work to consider vortex pairs. Co-rotating pairs were observed to move together and coalesce into a single vortex as they were adverted downstream In recent years, the use of vortex generators in channel flow applications h as received considerable attention. delta wing, rectangular wing, delta winglet, and rectangular winglet as vortex generators and utilized liquid crystal thermograph to measure the local heat transfer coefficient. Their results identified an increase in the local heat transfer coefficient in the order of several hundred percent and a mean heat transfer enhancement of more than 50%. studied the flow struc ture of an air stream over winglet pair type vortex generators. They found that the winglet pair produced a main vortex, a corner vortex, and an induced vortex. The main vortex was formed by flow separation at the leading edge of the winglet, while the corner vortex was generated by the deformation of the near wall vortex lines at the pressure side of the winglet. studied the interactions of delta-wing type vortex generators with the boundary layer on a flat plate. Their results identified a 50–60% enhancement of the average heat transfer analyzed three-dimensional unsteady laminar flow and heat transfer in a channel with a pair of inclined block shape vortex generators. They found unsteady flow occurred at ReH> 1000. When the thickness and span angle is increased, stronger and bigger stream wise vortices are formed downstream of the vortex generators. considered the application of delta, rectangular, delta winglet, and rectangular winglet type vortex generators in fin-tube heat exchangers. These studies investigated various geometric parameters, including aspect ratio and angle of attack. It is shown that the ratio of heat transfer to flow loss was highest when a delta winglet vortex generator was used with an angle of attack of 30° and with an aspect ratio of 2.

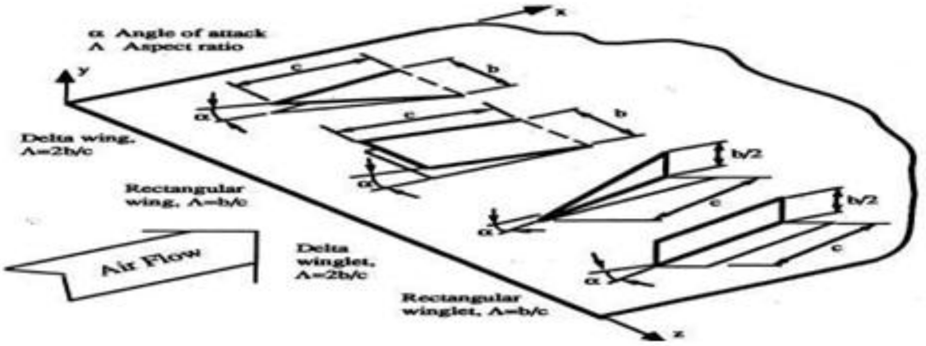

Fig 1:Vortex generators and the associated geometrical definitions

For the inline tube arrangement, the vortex generator increases the heat transfer coefficient by 55–65%, resulting in a corresponding increase of 20 - 45% in the apparent friction factor. This is proposed a novel strategy that can augment heat transfer but nevertheless can reduce pressure-loss in fin-tube heat exchanger in a relative low Reynolds number flow, by deploying delta winglet- type vortex generators. In case of staggered tube banks, the heat transfer was increased by 10–30%, and yet the pressure loss was reduced by 34–55%. In the case of in-line tube banks, the heat transfer was augmented by 10–210% together with the pressure loss reduction of 8– 15%. utilized a dye-injection technique to visualize the flow structure for annular and delta winglet vortex

generators. For the same winglet height, the delta winglet vortex generator shows more intensively vertical motion than that of annular vortex generator; while, the corresponding pressure drops of the delta winglet vortex generator are lower than those of annular vortex generator. Numerically and experimentally studied the wave-type vortex generator in plate-fin and tube heat exchangers. Their study identifies a maximum improvement of 120% in the local heat tranfer and an improvement of 18.5% in the average heat transfer coefficient. Reference to the journal of Jin-Sheng Leu [15] above details been concluded. Jin-Sheng Leu [15] 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. The case of α = 45° provides the best heat transfer augmentation. the delta winglet with common flow up configuration will also provide best heat augmentation. The foregoing literature review shows that no related comparison study of 3D numerical analysis for a different shaped vortex generator for a plate-fin and tube heat exchanger has been published. This has motivated the present investigation.

II. NUMERICAL SIMULATION

Numerical Simulation is to perform by a computational fluid dynamics for the heat transfer and fluid flow for the temperature distribution and local flow structure. The comparisons of heat transfer enhancement with flat tube-fin element with and without vortex generator enhancement under different shaped vortex generators carried out and optimized shape for heat transfer is been verified. The major parameters influencing the performance for vortex generator are the position, size and span angles. The present investigation mainly aims to evaluate the effects of span angle a on the thermal hydraulic characteristics. Three different span angles α = 300, 450and 600are investigated in detail for the Reynolds number ranging from 500 to 2500. Turbulent numerical simulations for the fluid flow and heat transfer over a 3-row tube is to be performed, and the effect of turbulence is simulated using computational fluid dynamics The conjugated convective heat transfers in the flow field and heat conduction in the fins are also considered.

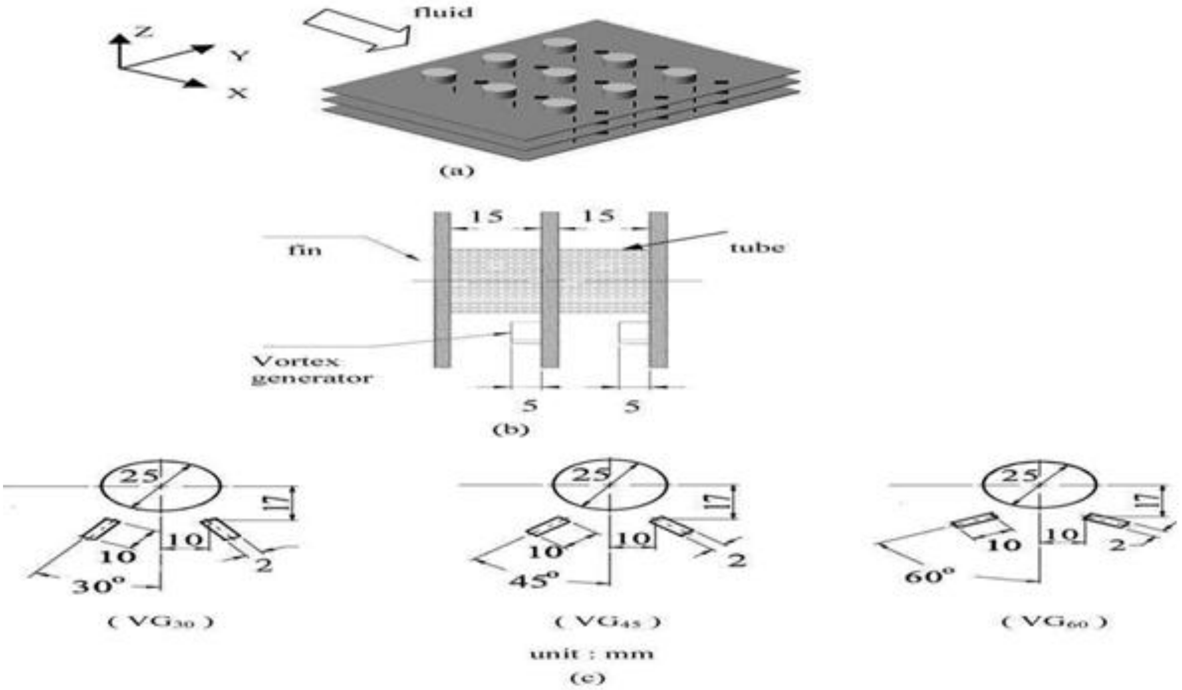

Fig.21. Physical model and relevant geometrical dimensions of the vortex generators.
(a) Physical model top view, (b) side view, & (c) three different span angles.

The fluid is considered incompressible with constant properties and the flow is assumed to be turbulent, steady and no viscous dissipation. The conjugated convective heat transfers in the flow field and heat conduction in the fins are also considered. At this boundary, the flow velocity is assumed to be uniform, and the temperature inlet is taken to be 200C. The intensity of the turbulence at the inlet is set to 3%.At the downstream end of the computational domain, located seven times the tube diameter from the last downstream row tube, stream wise gradient (Neumann boundary conditions) for all the variables are set to zero. At the solid surfaces, no-slip conditions and constant tube wall temperature Tw (700C) are specified. The delta winglet pair with common flow up configuration on the fin surface, as shown in 3.With this configuration, the winglet pair can create constricted passages in aft region of the tube which brings about separation delay . The fluid is accelerated in the constricted passages and as a consequence the point of separation travels downstream. Narrowing of the wake and suppression of vortex shedding are the obvious outcome of such a configuration which reduce form drag. Since the fluid is accelerated in this passage, the zone of poor heat transfer on the fin surface is also removed from the near wake of the tube In case of a low Reynolds number flow in absence of any vortex generators, the poor heat transfer zone is created widely on the fin surface in the near-wake of the tube and may extend far downstream even to the next row of the tube bank. Hence it is expected that the present strategy may be more effective for a lower Reynolds number flow.

III. CALCULATION TO FIND HEAT TRANSFER (H)

Calculation to Find Heat Transfer (h) The dimensionless time averaged equations for continuity, momentum (Reynolds-averaged Navier–Stokes equations) and energy maybe ex-pressed in tensor form

$$\frac{\partial U_i}{\partial X_i} = 0 \qquad (1)$$

$$\frac{\partial}{\partial X_j}(U_i U_j) = -\frac{\partial P}{\partial X_i} + \frac{1}{Re}[\nabla^2 U_i] - \frac{\partial}{\partial X_j}(\overline{u_i u_j}) \qquad (2)$$

$$\frac{\partial}{\partial X_j}(\Theta U_j) = \frac{1}{RePr}[\nabla^2 \Theta] - \frac{\partial}{\partial X_j}(\overline{u_j \theta}) \qquad (3)$$

:

The Reynolds number represents the ratio of the importance of inertial effects in the flow, to viscous effects in the flow.

Reynolds number, Where U, is the flow velocity, R is the radius of the cylinder, and ρ and μ are the fluid properties

Re = 1.109 x 0.025 x 1.71.941x10^{-5}

Where hydraulic diameter (h d) is 0.025

Velocity = 1.7

Re = 2428

Nusselt number correlation for cross flow over tube banks for N>16 and 0.7 < Pr > 500 and Reynolds number greater than 1000

Nusselt number is given by NuD = 0.27 ReD0.63 Pr0.36 (Pr/Prs) 0.25

NuD = 0.27 (2428)0.63 0.72410.36 (0.7241/0.7177) 0.25

NuD = 32.701

hence NuD = 32.701x 0.86

NuD = 28.12

To find Heat transfer

NuD = h D/ K

28.12 = h x 0.024

0.02699

h = 31.66 or 32

Heat transfer is been validated with the result which is obtained from the Computational Fluid Dynamics. It is found that the values are approximately equal as the value of h is 32.67466 in Computational Fluid Dynamic.

IV. RESULTS AND DISCUSSION

4.1. Heat transfer: Delta winglets with common flow up configuration in a fin-tube bank in an in-line tube arrangement successfully Increase the average heat transfer by10%to20%, the result indicates triangle winglet of span angle of 450 provides the best heat transfer augmentation which are seen in different tables.

TABLE 1: Heat Transfer augmentation for 10% increase in heat

Re	BASE		REC 45	TRI 45
500	3.592097		5.059579	5.275462
1000	5.397021		6.595592	7.283932
1500	7.246089		8.080419	8.986521
2000	8.23836		8.981102	10.1776
2500	9.226018		9.763312	12.47091

TABLE 2 : Heat Transfer augmentation for 20% increase in heat

Re		BASE			REC 45			TRI 45	
500		0.634107			0.634107			0.690487	
1000		1.516281			1.815082			1.63876	
1500		3.480423			4.26515			4.060486	
2000		5.530667			6.813886			6.209521	
2500		8.538239			10.14105			9.253577	

4.2.Pressure drop: Delta winglets with common flow up configuration in fin-bank in a in-line tube arrangement indicates span angle of 450 provides less pressure drop

Table-3 : Pressure Drop

FIN TYPES	30deg	45deg	60deg
BASE	32.67466	---	---
RECTANGLE	34.83991	39.090824	38.855183
RECTANGLE	37.73119	38.348999	38.647732

V. CONCLUSION

Delta winglets with common flow up configuration in a fin-tube bank in an in-line tube arrangement successfully Increase the average heat transfer by10%to20%, the result indicates triangle winglet of span angle of 450 provides the best heat transfer augmentation comparatively with all other fin geometries.

REFERENCES

[1] Chunhua Min , Chengying Qi, Xiangfei Kong, Jiangfeng Dong (2010)"Experimental study of rectangular channel with modified rectangular longitudinal vortex generators" International Journal of Heat and Mass Transfer 53 ,pp .3023–3029

[2] F.J. Edwards, G.J.R. Alker, The improvement of forces convection surface heat transfer using surfaces protrusions in the form of (A) cubes and (B) vortex generators, in Proceedings of the 5th International Conference on Heat Transfer, Tokyo, vol. 2, 1974, pp.244–248.

[3] P.A. Eibeck, J.K. Eaton, Heat transfer effects of a longitudinal vortex embedded in a turbulent boundary layer, ASME J. Heat Transfer 109 (1987) 37–57.

[4] W.R. Pauley, J.K. Eaton, Experimental study of the development of longitudinal vortex pairs embedded in a turbulent boundary layer, AIAA J. 26 (1988) 816–823 .

[5] S.T. Tiggelbeck, N.K. Mitra, M. Fiebig, Experimental investigations of heat transfer enhancement and fl ow losses in a channel with double rows of longitudinal vortex generators, Int. J. Heat Mass Transfer 36 (1993) 2327-2337.

[6] M. Fiebig, H. Guntermann, N.K. Mitra, Numerical analysis of heat transfer and flow loss in a parallel plate heat exchanger element with longitudinal vortex generators as fins, ASME J. Heat Transfer 117 (1995)1064–1067.104

[7] G. Biswas, K. Torii, D. Fujii, K. Nishino, Numerical and experimental determination of flow structure a nd heat transfer effects of longitudinal vortices in channel flow, Int. J. Heat Mass Transfer 39 (1996) 3441–3451.

[8] M.C. Gentry, A.M. Jacobi, Heat transfer enhancement by delta-wing-generated tip vortices in flat-plate and developing channel flows, ASME J. He at Transfer 124 (2002) 1158–1168.

[9] A. Sohankar, L. Davidson, Effect of inclined vortex generators on heat transfer enhancement in a three dimensional channel, Number. HeatTransfer, Part A 39 (2001) 433–448.

[10] M. Fiebig, A. Valencia, N.K. Mitra, Wing-type vortex generators for fin-and-tube heat exchangers, Exp. Therm. Fluid Sci. 7 (1993) 287–295.

[11] A. Valencia, M. Fiebig, N.K. Mitra, Heat transfer enhancement by longitudinal vortices in a fin-and-tu be heat exchangers element with flattubes, ASME J. Heat Transfer 118 (1996) 209–211.

[12] K. Torii, K.M. Kwak, K. Nishino, Heat transfer enhancement accompanying pressure-loss reduction with winglet type vortex generators for fin-tube heat ex changers, Int. J. Heat Mass Transfer 45 (2002) 3795– 3801.

[13] C.C. Wang, J. Lo, Y.T. Lin, C.S. Wei, Flow visualization of annular and delta winglet vortex generators in fin-and tube heat exchanger application, Int. J. Heat Mass Transfer 45 (2002) 3803–3815.

[14] C.N. Lin, J.Y. Jang, Conjugate heat transfer and flu id flow analysis in fin-tube heat exchangers with wav e-type vortex generators, J. Enhanc. Heat Transfer 9 (2002) 123–136. Experiments, ASME, Mech. En g. 75 (1953) 3–8.

[15] Jin-Sheng Leu , Ying-Hao Wu , Jiin-Yuh Jang , (2004) ,"Heat transfer and fluid flow analysis in plate- fin and tube heat exchangers with a pair of block shape vortex generators" International Journal of Heat a nd Mass Transfer 47, pp.4327–4338- 105