Journal of Material Science and Mechanical Engineering (JMSME)
p-ISSN: 2393-9095; e-ISSN: 2393-9109; Volume 3, Issue 7; October-December, 2016 pp. 471-474

http://www.krishisanskriti.org/Publication.html

CFD Analysis of Fin and Tube Compact Heat Exchangers with Rectangular and Wavy Rectangular Winglet-Type Vortex Generators

Shreeti Bhati[1], Preeti Kumari[2] and H. C.Thakur[3]

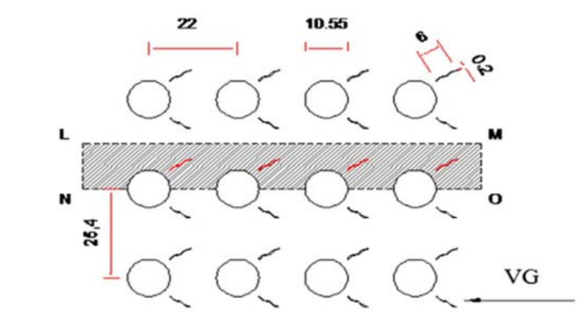
[1,2]*Mechanical Department, Gautam Buddha University, Greater Noida*
[3]*Gautam Buddha University, Greater Noida*

Abstract—*For compact heat exchanger, improving heat transfer by expanding amount of fins leads to cost and load penalty. In recent research, establishing different vortex generator fins are causing heavy vortices and enhance the performance of heat exchanger without demanding to increase the volume of fins. In this paper heat transfer analysis has been done of fin and tube compact heat exchanger. For heat transfer enhancement we use two configuration such as rectangular and wavy winglet. The whole analysis for various configurations have been done in ANSYS 14.5*

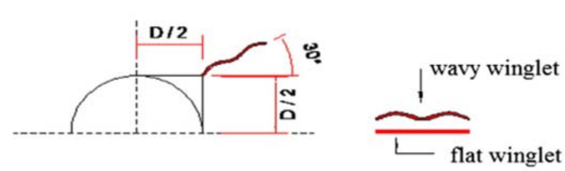
Keywords*: heat exchanger, heat transfer enhancement, fin- tube heat exchanger, vortex generation.*

1. INTRODUCTION

Fin and tube heat exchangers in different engineering fields, such as heating, Ventilation, air conditioning and refrigeration systems are generally used . Compact heat exchangers are widely used in industries, so enhancement in their performance with respect to reducing manufacturing costs by using less material. To achieve higher heat transfer rate through a variety of augmentation methods can result in significant energy savings such as more compact, less cost and higher thermal efficiency. Heat exchanger work is usually defined through the gas side. Heat exchangers includes liquid- fluid flow to air flow and phase change, the air-side convection resistance is mostly dominant being thermo- physical properties of air ,which results heat transfer coefficients are less for gas side than for liquid. To enhance the air-side heat transfer performance of fin and tube compact heat exchanger. There are two methods or technique of heat transfer enhancement such as active and passive. With significant heat transfer enhancement and pressure drop penalty associated for those have been formed and various fin patterns like wavy, louver and slit fin conventional heat transfer enhancement methods. One of the most important passive techniques to augment the heat transfer is the use of vortex generators. Vortex is an aerodynamic device , consisting of a small vane usually attached to a lifting surface (or airfoil, such as an aircraft wing)or a rotor blade of a wind turbine. When fluid flow by vortex generators, stream-wise vortices are generated in flow field due to flow separation about leading point of vortex generator. It causes bulk flow mixing, boundary-layer adjustment, and flow destabilization, heat transfer augment due to these vortices. The longitudinal vortex generators applied in several heat exchangers have obtain considerable attentions lead to a pressure drop penalty. The advantages of vortex generator is to increase gas mileage performance, down force, top speed and velocity and also variety of experimental and numerical research works. Fiebig et al.stated that the vortex generators with delta form were found to be more efficient per unit area than other designs. Zhou and Ye experimentally investigated the curved trapezoidal winglet as a new form of vortex generators. The results of trapezoidal winglet and delta winglet were compared with a rectangular winglet by taking that the best laminar and exchanger with two different forms of winglet vortex generator shape. All dimensions are in mm.



a) - Schematic of 2D compact heat exchangers with wavy rectangular winglet vortex generators



b) - Position of wavy rectangular winglet

Fig. 2: Computational domain of fin-and-tube compact heat

transitional flow region delta winglet pair, although curved trapezoidal winglet pair include better thermo- hydraulic performance in turbulent region perfectly because of streamlined configuration and low pressure drop. By this, the advantages of this type of vortex generator has been specified for heat transfer enhancement.

2. LITERATURE REVIEW

Fiebig et al. [1] experimentally investigated three tube along delta winglet placed in each rows in heat exchanger. As inline arrangement, friction factor increases with heat transfer enhancement. Some shapes in which local heat transfer enhancement by 10% for round tubes and 100% for flat tubes.. Extended their earlier work and by evaluating the impact of vortex generation in channel flows. For evaluating, rectangular and delta wings and winglet with unsteady , liquid crystal thermography technique for aspect ratios varying from 0.8 to 2.0, angles of attack varying from 10 to 60, and Reynolds numbers varying from 1000 to 2000.Tiggelbeck et al. [2] By using rectangular winglets, extended with multiple row vortex generation in staggered form of vortex generator and pressure drop experiments includes qualitative flow structure, number of vortices per generator and stream wise development work. Then ,were noted to be approximately independent of upstream flow conditions. Higher heat transfer enhancements and pressure drop in inline arrangement than staggered arrangement Reynolds number of 6000, average heat transfer was increased 80% for an angle of attack of 45 ^{0}.**Chen et al. [4]** numerically investigated, both in-line and staggered arrangement includes heat transfer and fluid flow in an oval-tube heat transfer element by using punched winglet type vortex generators. Again, the winglets placed in staggered form increase heat transfer achievement finned elliptical tube heat exchanger. Heat transfer enhancement is more in staggered arrangement than in inline arrangement. **Valencia et al. [3]** showed the winglets is placed downstream of tube symmetrically which give optimal location of generators. To improves the heat transfer often with up of the tube which described by a poor heat transfer coefficient. **Leu et al [5]** numerically and experimentally studied the different vortex generator such as block shape and inclined block shape vortex generators is placed behind the tubes includes heat transfer and fluid flow in plate-fin and tube heat exchanger. They indicated that proposed heat transfer enhancement performance in the wake region. **Biswas et al. [6]** numerically investigated built-in circular tube and delta-winglet pair vortex generators comprises of flow and the heat transfer . They have studied and found significant heat transfer enhancement directly downstream of the tube. **Gentry and Jacobi [8**], **Biswas et al.** identified the strength of vortex and thus enhancement of heat transfer performance, by increasing the angle of attack and Reynolds number of delta winglets. At the leading edge of flat plate with dfferent vortex generator has been mounted and the heat transfer enhancement also studied. In delta-wing vortex generatror, validation upto 50– 60% growth in average heat transfer over the surface of the plates. It signifies that delta-wing is similar to isosceles triangle which is mounted symmetrically to the flow and angle of attack is measured between the plate and the lean of the delta, but at an incident angle measured parallel to the inlet flow and maximum enhancement occurring at an angle of attack of 40^{0} and the angle of attack varies from 25˚ to 55˚.**Torii et al. [9]** used experimentally different configurations like common-flow-up and common-flow-

NOMENCLATURE

A	total heat transfer surface area [m2]	Cp	specific heat [J/kg K]
Dc	tube outside diameter [m]	Dh	hydraulic diameter [m]
f	friction factor	Re	Reynolds number
k	thermal conductivity [W/m2-K]	N	number of tube row
Nu	Nusselt number (h Dh/k)	mf	mass flow rate [kg/s]
ΔP	pressure drop [Pa]	L	chord length of the winglet[m]
Pl	longitudinal pitch [m]	Pr	Prandtl number
Pt	transverse pitch [m]	Q	heat transfer rate [W]
Um	mean velocity at the minimum flow cross-sectional[m/s]	T	Temperature [K]
β	attack angle of the delta winglet (deg	δ	delta winglet thickness
μ	dynamic viscosity [kg/ms]		
h	heat transfer coefficie [W/m2· K]		

down in delta winglets for plate fin-and-tube heat exchanger with less Reynolds number. These winglets were not completely based on upstream or downstream part of tubes, although were placed along sides of the tubes. The winglet-type vortex generator were used which results in increase in overall heat transfer coefficient. Also, configuration with common-flow-up give more overall heat transfer coefficient. It causes significant separation delay, reduces drag, and removes less heat transfer area from the near-wake of the tubes. **Zhou and Ye [10]** by analysing the form of curved trapezoidal winglet vortex generators which give results and related to a rectangular winglet, trapezoidal winglet and delta winglet using dimensionless factors. In laminar and transitional flow area, delta winglet is better, although in turbulent region thermo-hydraullic performance is better in curved trapezoidal winglet pair. As a result , streamlined configuration and less pressure drop, which indicates to obtain the benefits of this type of vortex generators for heat transfer enhancement. Because of larger pressure drop, two rows of curved trapezoidal winglet pair do not give best thermo-hydraulic performance and the spacing between the two rows of curved trapezoidal winglet pair also improved.

3. METHODOLOGY

3.1 GEOMRTRIC MODELLING

The computational domain with different forms of winglets such as rectangular , wavy-up and wavy-down rectangular winglet for the fin-and-tube compact heat exchanger. Due to symmetry as shown in fig 2b.The tube outside diameter 'Dc' is10.55mm, and longitudinal tube pitch 'Pl' is 22mm. The base chord length 'l' is 6mm, the thickness of wavy winglet 'δ' is 0.2mm and the attack angle 'β' of vortex generator is 45˚.

3.2 GOVERNING EQUATION

The fluid is incompressible, flow is assumed to be laminar and steady.Thermophysical properties are constant. Thermal contact resistance is ignored in between tube and fin. The following equations are used.

Continuity equation:

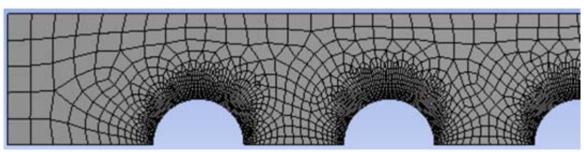
$$\frac{\partial \rho u_i}{\partial x_i} = 0$$

Momentum equations:

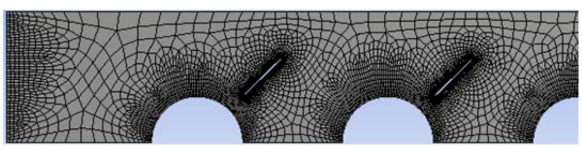
$$\frac{\partial\,(\rho u_i u_j)}{\partial x_i} = \frac{\partial}{\partial x_i}\left(\mu \frac{\partial u_j}{\partial x_i}\right) - \frac{\partial p}{\partial x_j}$$

Energy equation:

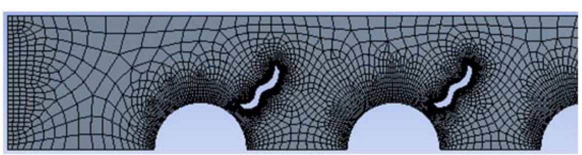
$$\frac{\partial(\rho u_i T)}{\partial x_i} = \frac{\partial}{\partial x_i}\left(\frac{k}{c_p}\frac{\partial u_j}{\partial x_i}\right)$$



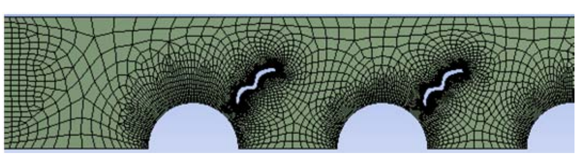
(a) Baseline case



(b) Flat Rectangular winglet case



c)Wavy-up rectangular winglet case



(d)Wavy-down rectangular winglet case

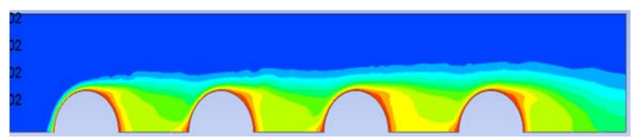
Fig. 3. Grid generation around compact heat exchangers and tubes,(a) baseline case without vortex generator (b) conventional flat rectangular with winglet-type vortex generators and tubes, and (c, d) wavy rectangular winglet-type vortex generators and tubes with down and up case winglet forms.

4. BOUNDARY CONDITION

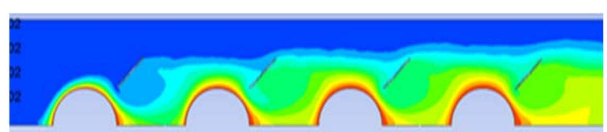
At Reynolds number 400, Temperature contours are established by using the following boundary conditions. The inlet uniform velocity is evaluated from the above Reynolds number. Temperature at inlet is 300 k. No slip boundary condition. Temperature distribution at the wall is 350 k.

5. RESULTS AND DISCUSSION

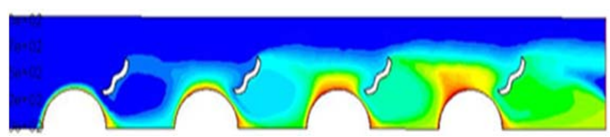
In research, as fin-and-tube heat exchangers the significance of wavy-up and wavy-down rectangular winglets with the heat transfer component and flow arrangement. Analysis has been done in fin and tube heat exchanger by using rectangular winglet or without winglet is observed. In numerical approach, at inlet velocity Reynolds number varies from Re = 400 to 800 for in-line structure as shown in fig. To represent all the temperature contour for baseline case without winglet, flat rectangular winglet, wavy-up and wavy-down rectangular winglet type vortex generators, respectively in in-lined formation. By numerical analysis it determined that the moderatetemperature difference of air within in and out flow for wavy-up and wavy-down rectangular winglet vortex generators is more as compared to that of ordinary rectangular winglet and baseline case. Inclusion of wavy up shape of rectangular winglets give the best heat transfer achievement. In order to improve heat transfer enhancement with wavy-up and wavy-down shape of rectangular winglet.



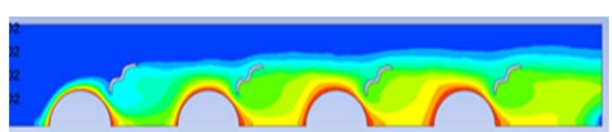
(a) Baseline case



(b) Flat Rectangular winglet case



(c) Wavy-up rectangular winglet case



(d) Wavy-down rectangular winglet case

6. CONCLUSION

In this review paper the vortex generator technique is a way of heat transfer enhancement. There are several desirable and cost effective technique to increase the heat transfer by using vortex generator. In heat exchanger, the effect of vortex generator on heat transfer enhancement is reviewed and expressed. The development of shape, angles of attack, location with tubes, and Reynolds is further studied.

7. ACKNOWLEDGEMENT

We would like to thanks our guide Dr Harish Chandra Thakur to give their support .

REFERENCES

[1] A. Valencia, M. Fiebig, N.K. Mitra, W. Leiner, Heat transfer and flow loss in a fin-tube heat exchanger element with wingtype vortex generators, Inst. Chem. Eng. Symp. Ser. 129 (1) (1992) 327–333.

[2] A. Sinha, K. Ashoke Raman, H. Chattopadhyay, G. Biswas, Effects of different orientations of winglet arrays on the performance of plate-fin heat exchangers, Int. J. Heat Mass Transf. 57 (1) (2013) 202–214.

[3] G. Biswas, N.K. Mitra, M. Fiebig, Heat transfer enhancement in fin–tube heat exchangers by winglet type vortex generators, Int. J. Heat Mass Transf. 37 (2) (1994) 283–291.

[4] G. Biswas, K. Torii, D. Fujii, K. Nishino, Numerical and experimental determination of flow structure and heat transfer effects of longitudinal vortices in a channel flow, Int. J. Heat Mass Transf. 39 (16) (1996) 3441–3451.

[5] G. Zhou, Q. Ye, Experimental investigations of thermal and flow characteristics of curved trapezoidal winglet type vortex generators, Appl. Therm. Eng. 37 (2012) 241–248.

[6] H.E. Ahmed, H.A. Mohammed, M.Z. Yusoff, An overview on heat transfer augmentation using vortex generators and nanofluids: approaches and applications, Renew. Sust. Energ. Rev. 16 (8) (2012) 5951–5993.

[7] J.S. Leu, Y.H. Wu, J.Y. Jang, Heat transfer and fluid flow analysis in plate-fin and tube heat exchangers with a pair of block shape vortex generators, Int. J. Heat Mass Transf. 47 (19–20) (2004) 4327–4338.

[8] K. Torii, K.M. Kwak, K. Nishino, Heat transfer enhancement accompanying pressureloss reduction with winglet-type vortex generators for fin–tube heat exchangers, Int. J. Heat Mass Transf. 45 (18) (2002) 3795–3801.

[9] M. Fiebig, A. Valencia, N.K. Mitra, Wing-type vortex generators for fin-and-tube heat exchangers, Exp. Thermal Fluid Sci. 7 (4) (1993) 287–295.

[10] M.C. Gentry, A.M. Jacobi, Heat transfer enhancement by delta-wing-generated tip vortices in flat-plate and developing channel flows, J.Heat transfer 124(6) (2002)1158-1168.