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Experimental Analysis of Delta Winglet Type Vortex Generator Attached on Tube Surface of Tube in Tube Heat Exchanger for Heat Transfer Enhancement

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Abstract— The Vortex generator is responsible for creating the turbulence in flow of fluid. Delta winglet type vortex generator is used enhance the heat transfer rate in tube in tube heat exchanger. The vortex generators are directly welded on internal side of tubes of tube in tube heat exchanger, which results in to stream wise longitudinal vortices in the tube which disrupt the growth of thermal boundary layer and enhance the heat transfer rate. Influence of geometrical parameter such as aspect ratio, winglet attack angle on heat transfer is studied on rectangular, square, triangular and delta type winglet vortex generator and pressure drop is also calculated to find out the effect on heat transfer rate. Air is taken as working fluid. The flow regime is assumed to be laminar. By varying the above parameter the heat transfer coefficient is calculated and compares all result optimum Dimension of winglet is selected. From the experimentation, delta winglet type vortex generator with size 15mm x 20mm with 30° attack angle has high heat transfer coefficient and high heat transfer rate as compared with other types of winglet vortex generator.

Index Terms— Aspect ratio, Attack angle, Heat transfer coefficient, Delta winglet shape, Rectangular winglet shape, Thermal boundary layer,

1 INTRODUCTION

Heat exchangers are heat transfer devices used for exchange of heat between two fluids that are at different temperatures. Heat exchangers are commonly used in heating applications and refrigeration and air-conditioning systems in a domestic, chemical processing and power production in big plants.

In a tube in tube heat exchanger, heat is transferred from the hot water flowing through the tubes to the air flowing through the closely spaced thin plates outside attached to the tubes. In heat exchanger, heat transfer involves convection mode in each fluid and conduction through the wall separating the two fluids. The temperature difference is drive force to transfer heat from one fluid to other fluid in heat exchanger. In tube in tube heat exchanger temperature difference varies along the length of tube therefore rate of heat transfer between the two fluids goes on changing. Tube in tube heat exchanger consists of two tubes, inner tube and outer tube which are coiled together. Tube in tube heat exchanger is perfect for high temperature, high pressure and low flow application. This type of heat exchanger are used for cooling, heating or reheating of fluids, gases or air in wide range of productions such as chemicals processing, hydro carbon processing etc.

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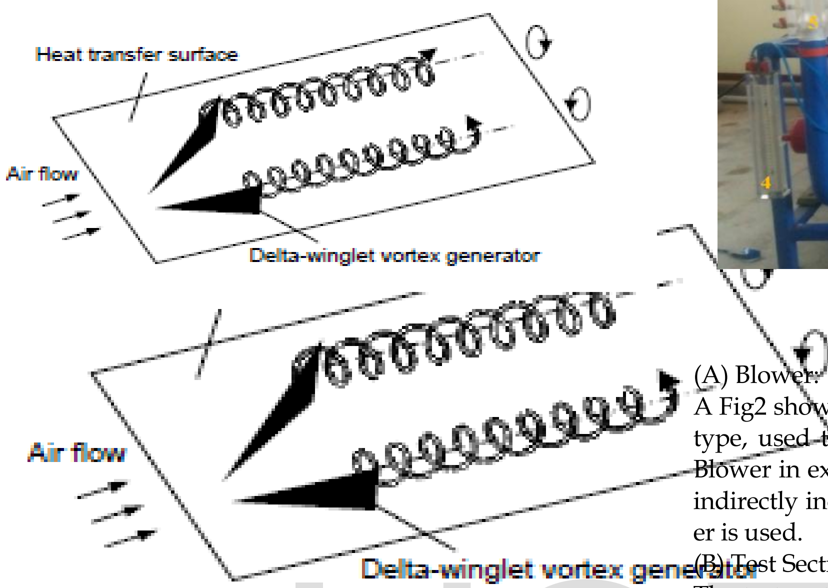
Vortex generators are responsible for enhancement of heat transfer in tube in tube heat exchanger. Turbulence is created by using vortex generators. These vortex generators are in the form of wings or winglets. These vortex generators are of triangular, rectangular or delta shapes which can weld or punched and bend out of plates so that they can create turbulence in the path of flow to main flow direction. When trailing edge is attached to tube is called as wing and when the chord length is attached to tube is called as winglet. In this delta winglet type vortex generator is used which are mounted directly inner surface of tube by welding. By varying size of winglet and by varying their configuration heat transfer coefficient will be calculated. Two widely used techniques are interrupted fins and vortex generation. Vortex generation is technique that holds assurance in surface convection enhancement. In this method, vortex generator (VG), is punched or welded on a heat-transfer surface. As the flow encounters the VG, the pressure gradient causes the boundary layer to separate along the leading edge and form a vortex system as shown in figure1.1. The vortices are advocated downstream and continue for a length of vortex generator. Presence of the vortices improves heat transfer by boundary layer modification, improved mixing, and flow deterioration. The vortex generator enhancement technique can be implemented with low cost and ease. This method of heat transfer enhancement is having moderate pressure drop penalty. Substantial research has been undertaken on heat transfer augmentation by vortex generation for different generator shapes, surface geometries, and flow conditions



2 Experimentation

2.1 Experimental Setup

To study the heat transfer enhancement in tube in tube heat exchanger using delta winglet type vortex generator the experimental facility used is a simple forced convection setup. The test section or tube is fitted with the blower for forced convection environment. Blower is used in this experimental setup as air is used as a working fluid. Heating coil is provided around the tube for heating the outer surface of tube. Different winglet shapes are welded on inner side of tube in tube heat exchange. These different winglet shape tubes are inserted in the tube. Different tubes are manufactured for the different winglet shape such as rectangular, square, triangular and delta. By inserting the different tubes of different shape in the test sections reading for temperatures were taken to calculate the heat transfer coefficient.

Dimensions of test section:

Length of Test Section: 600 mm.
Length of Calming Section: 1000 mm.
Inner Diameter of Tube (Di): 54 mm.
Outer Diameter of Tube (Do): 56 mm.

The experimental setup consists of following main components:

(A) Blower
(B) Test Section
(C) Calming Tube
(D) Venturimeter
(E) Manometer
(F) Heater
(G) Thermocouples and Control Panel

Fig. 2. Experimental Setup

(A) Blower:
A Fig2 show blower is used in experimental setup is centrifugal type, used to circulate the air in tube in tube heat exchanger. Blower in experimental setup used for forced convection which indirectly increases the heat transfer rate. 0.5 HP capacity blower is used.

(B) Test Section:
The test section shown in Fig2is length of tube in which vortex tube is to be placed and is heated from outside. The test section length selected is 600 mm and the length of the cross plate is 600 mm. Inner Diameter of test section is taken as 54mm and Outer Diameter 56 mm.

(C) Calming Tube:
The Calming tube section is provided to allow the flow to be hydro-dynamically fully developed shown in Fig2.

(D) Venturimeter:
It is used to measure the mass flow rate, and thereby velocity of water. The Venturimeter shown in Fig2is fitted across the delivery side of the pump to avoid the effect of its back pressure on test section. The volumetric flow rates from the pump were adjusted by Flow control valve fitted at delivery end.

(E) Manometer:
U-tube manometer is used to measure the pressure drop across the test section. The range of the manometer is 0-300mm of water column.

(F) Heater:
Uniform heat flux is applied to the test tube by heating it with band heater. The mechanism of heat production is based on principle of electrical resistance heating. The electrical output power can be controlled by a dimmer stat to provide constant heat flux along the entire length of the test section. The capacity of heater is 300 watt, 230 V AC supply is to be provided.

(G) Thermocouples and Control Panel:
The surface temperature of the tube wall is measured by K type thermocouples, which are placed on the surface of the tube. Eight thermocouples are placed on the surface of the test section to measure the surface temperature and two thermocouples are placed at the inlet and outlet of the test section to measure the

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inlet and outlet temperature of the water. To measure the outer surface temperature of insulation two thermocouples are mounted at outer surface of insulation. The range of thermocouple is 0-200˚C. Control Panel consists of dimmer stat, temperature indicator and on-off switch shown in Fig2.

2.2 Selection of Vortex Generator

a. Vortex generators are proposed in different geometries such as Delta rectangular, winglet, triangular etc.
b. Winglet and triangular vortex generators are the simplest types which the least pressure drop is reported for them referred from literature survey.
c. The best size dimensions for length to height ratio are 2 to 1for winglets to have the best heat transfer referred from literature survey.
d. The best angle of attach is reported 30º.By increasing the angle of attack, both pressure drop and heat transfer will be increased referred from literature survey.

2.3 Different Winglet Shapes

A. Rectangular Shape

Rectangular shape winglet vortex generator are mounted in inside surface of tube heat exchanger with attack angle 30° and dimensions 40 mm x 20 mm. also pitch is kept constant i.e. 15 mm. As from the literature survey as attack angle 90° gives high pressure drop which is indirectly reduces heat transfer coefficient and it is also seen from literature survey winglets mounted with attack angle 30° gives least pressure drop and hence attack angle 30° is selected for all the winglet vortex generator

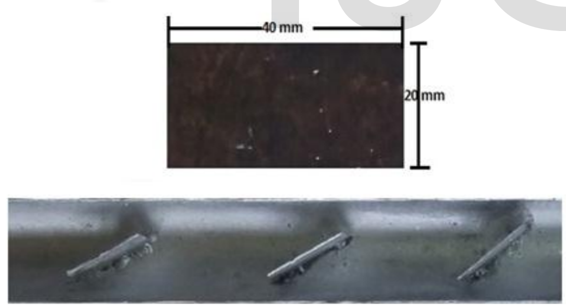

Fig3. Rectangular type of vortex generator

B. Square shape

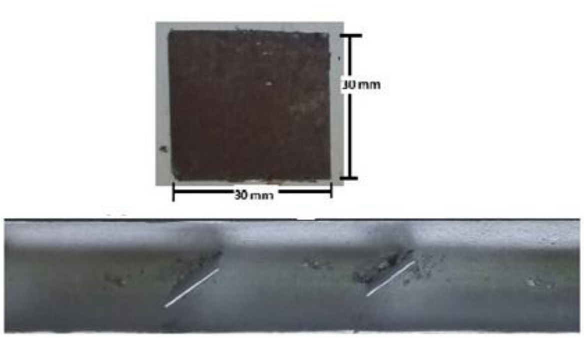

Fig4. Square type of vortex generator

As shown in figure square shape winglet vortex generator are mounted in inside surface of tube heat exchanger with attack angle 30° and dimensions 30 mm x 30 mm. also pitch is kept constant i.e. 15 mm.

C. Triangular shape

As shown in figure square shape winglet vortex generator are mounted in inside surface of tube heat exchanger with attack angle 30° and dimensions 30 mm x 30 mm. also pitch is kept constant i.e. 15 mm.As from the literature survey as attack angle 90° gives high pressure drop which is indirectly reduces heat transfer coefficient and it is also seen from literature survey winglets mounted with attack angle 30° gives least pressure drop and hence attack angle 30° is selected for all the winglet vortex generator. For the entire configuration attack angle 30° is selected from literature survey.

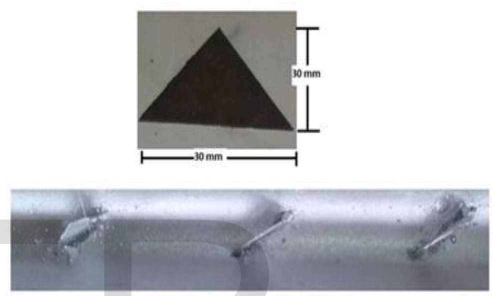

Fig5. Traingular type of vortex generator

D. Delta shape

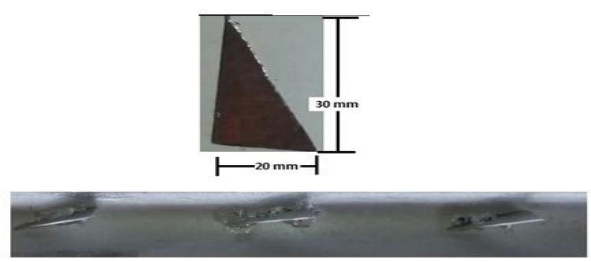

Fig6. Delta type of vortex generator

As shown in figure two delta winglet shapes are selected one with dimension 30 mm x 20 mm and one with 15 mm x 20 mm.As from the literature survey it is clear that as size goes on decreasing of winglet shape mounted on inside of tube surface it give better heat transfer rate and heat transfer coefficient goes in increasing.

2.4 Calibration of Experimental Setup

Calibration is the procedure to check the accuracy and correctness of the given experimental facility here the comparison made between the smooth tube result and result obtained from the previous correlations. In this present study, the heat transfer rate in terms of Nusselt number and pressure loss in terms of friction factor, for plain tube confirmed the results with the past correlations of Gnielinski for the Nusselt number while the friction factor was compared with Petukhov correlations. Verification tests of the heat transfer rate results in the plain tube are exhibited in Fig.22The results obtained from the present plain tube is in good agreement with previous correlations. These results revealed the accuracy of the experimental setup and the measurement technique.

Gnielinski correlation for Nusselt number is given as,

$$Nu = \frac{(f \div 8)(\mathrm{Re} - 1000)\,\mathrm{Pr}}{1 + 12.7(f \div 8)^{0.5}(\mathrm{Pr}^{2/3} - 1)}$$

Petukhov Correlation For friction factor is given as,

$$f = (0.790 \ln \mathrm{Re} - 1.64)\text{-}2$$

Another way to prove the accuracy and validity of experimentation is to test the process under any analysis software like computational fluid dynamics. A cad model can be made by any modeling software like CATIA, Pro-E, ANSYS Design Modeler etc. and is then fed to analysis software intern will give results. These results can be compared with experimental results and can show accuracy of testing facility available. This type of validation is also done for this work using ANSYS FLUENT 16.0 software.The Nusselt number is plotted against Reynolds number for the values obtained from experimental data and that from Gnielinski correlation in figure .The good agreement between Nusselt numbers obtained from experimental data and correlation shows that the experimental facilityisgood.

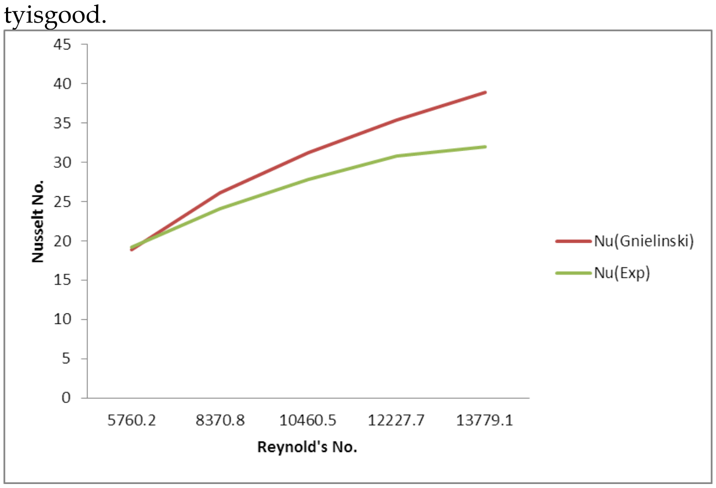

Fig5. Variation of Nusselt number with Reynolds number for Experimental data and Gnielinski correlation

3 Result & Discussion

3.1 Effect of Reynolds Number on Heat Transfer Coefficient

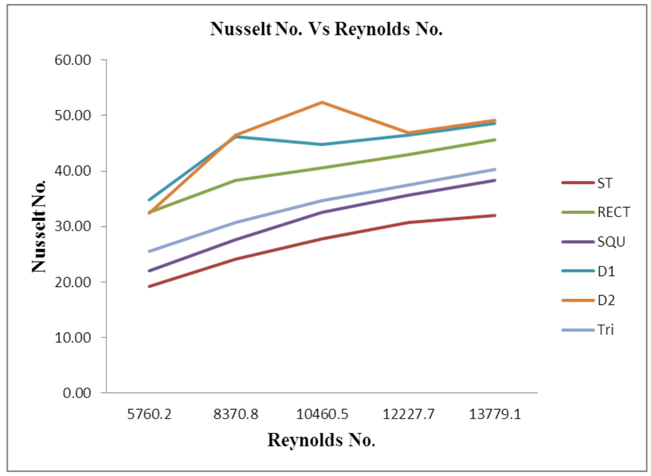

Fig6.Effect of Reynolds Number on Nusselt number for Various winglet shapes

Experimental values of heat transfer coefficient and Nusselt number for different shapes of winglet against the Reynolds number of air flow inside the test section with attack angle 30° are presented as shown in Figure. As the air flow past the winglets swirl flows are generated by flow separation along the side edge of the wings due the pressure difference. Presence of the wings disturbs the air flow inside the test section. It enhances the heat exchange between the test section and fluid. Results show that higher value of heat transfer coefficient for delta winglet shape (D2) with dimensions 15mm x 20 mm and winglet attack angle 30˚. By inserting square type winglet shape the heat transfer coefficient is increase by 49.55% which is the least value amongst this configuration. For delta winglet shape (D2) with dimensions 15 mm x20mm has higher percentage of increase of heat transfer coefficient is 70.2%. Also the higher value of Nusselt number is obtained for Delta winglet shape (D2) and the percentage increase of Nusselt number is 68.68%.

3.2 Effect of Reynolds Number on Pressure Drop

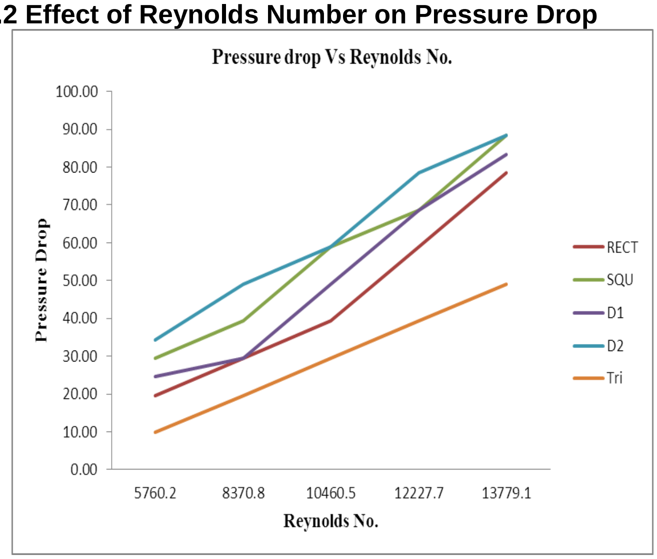

Fig7.Effect of Reynolds Number on pressure drop on various winglet shapes

Amongst the configuration tested for Delta winglet shape (D2) with dimensions 15mm x 20mm for attack angle 30° gives the best enhancement efficiency of 1.92 at Reynolds number 5760.2 and the least value of enhancement efficiency given by square type winglet vortex generator which is 1.20 at Reynolds number 13779.1.

3.3 Effect of Reynolds Number on enhancement efficiency

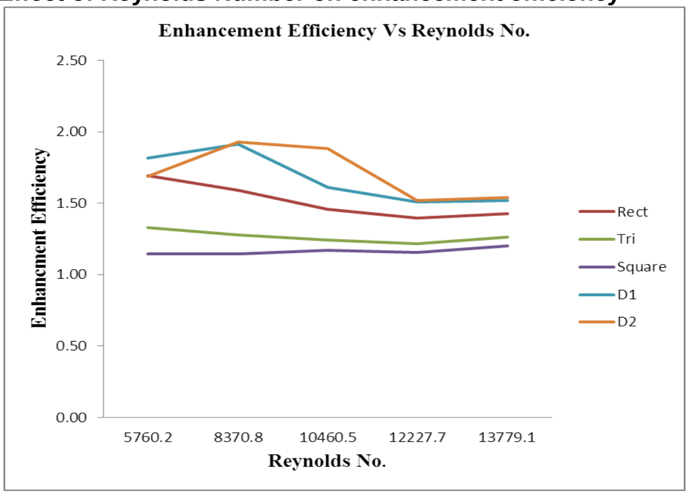

Fig8. Effect of Reynolds Number on enhancement efficiency number for various winglets shapes

As the obstacle provided in the path of air flow it will increase the pressure difference between upstream and downstream of the test section. Figure shows the Variation of pressure drop with Reynolds Number for different shapes of winglet vortex generator. Results shows that as the height of winglet vortex generator increases the pressure drop penalty is more also from the literature survey value of pressure drop increases with the increase in the wing attack angle. Wings with 90˚ attack angle provide the more obstruction to the air flow as compared to the attach angle 30˚. Hence the pressure drop penalty is more for the square type winglet vortex generator which is 88.29 Pa at Reynolds number 13779.2.

4 Conclusion

In the present work influence of three geometrical parameters on heat transfer rate in tube in tube heat exchanger with different winglet type vortex generator were analyzed experimentally. Also to validate the experimentation CFD analysis is done in ANSYS FLUENT 16.0 software. Total 5 configuration of winglet vortex generator were tested. It is found that the tube in tube heat exchanger with delta winglet type vortex generator welded on inner side of tube having better heat transfer coefficient than smooth tube.

1. By using the different configuration of winglet vortex generator increment in heat transfer coefficient is recorded as 30% to 60%.
2. Nusselt number is increase by 48% to 78%.The value heat transfer coefficient and Nusselt number increases with the decrease in aspect ratio.
3. Delta type of vortex generator with dimension 20mm x 30 mm has high heat transfer rate as compared to other type of vortex generator.
4. Pressure penalty is low in delta type of vortex generator (D1) & hence heat transfer coefficient and Nusselt number is high in delta type vortex generator (D1).
5. It is observed that enhancement efficiency is decreases with increase in Reynolds number that means the tubular heat exchanger with delta type of vortex generator (D1) gives the better performance at lower Reynolds number
6. As the aspect ratio goes on decreasing for Delta type vortex generator, number of vortices increases which results into the enhancement in heat transfer coefficient and Nusselt number.
7. Validation results are nearly equal to experimental results. Error occurred in experimental and CFD results, because of temperature measured in experimentation is at one point and CFD considers uniformity of temperature measurement.
8. In social point of view, enhancement of heat transfer by this method is useful in various applications such as boiler, heat exchangers used at chemical plants etc.

References

[1]. A.A. Gholami, MazlanA.Wahid, Heat transfer enhancement and pressure drop for fin-and-tube compact heat exchangers with wavy rectangular winglet-type vortex generators, International Communications in Heat and Mass Transfer (2014)

[2] G. Biswas,N.K.Mitra,M. Fiebig, Heat transfer enhancement in fin–tube heat exchangers 404 by winglet type vortex generators, Int. J. Heat Mass Transf. 37 (2) (1994) 283–291.

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

[4] Gentry, M. C., 1998, Heat Transfer Enhancement Using Tip and Junction Vortices, Ph.D. dissertation, University of Illinois, Urbana, IL.

[5] Gentry and Jacobi, Performance comparison of some tube inserts, Int. Comm. Heat Mass Transfer, 29, 45-56 (2002).

[6] Yuan, Z.-X., Tao, W.-Q., and Yan, X. T., 2003, Experimental Study on Heat Transfer in Ducts with Winglet Disturbances, Heat Transfer Engineering, Vol. 24(2), pp. 76-84.

[7] Dietz, C. F., Henze, M., Neumann, S. O., Wolfersdorf, J. von, and Weigand, B., 2006, The Effects of Vortex Structures on Heat Transfer and Flow Field behind Multielement Arrays of Vortex Generators, Proceedings of the 13th International Heat Transfer Conference, Paper No. HTE-12.

[8] Wu, J. M., Zhang, H., Yan, C. H., and Wang, Y., 2012, Experimental Study on the Performance of a Novel Fin-Tube Air

Heat Exchanger with Punched Longitudinal Vortex Generator, Energy Conversion and Management, Vol. 57, pp. 42-48.
[9] Min, C., Qi, C., Kong, X., and Dong, J., 2010, Experimental Study of Rectangular Channel with Modified Rectangular Longitudinal Vortex Generators, International Journal of Heat and Mass Transfer, Vol. 53, pp. 3023-3029.
[10] Fiebig, M., 1998, Vortices, Generators and Heat Transfer, Chemical Engineering Research and Design, Vol. 76(2), pp. 108-123.
[11] O'Brien, J. E., and Sohal, M. S., 2005, Heat Transfer Enhancement for Finned-Tube Heat Exchangers with Winglets, ASME Journal of Heat Transfer, Vol. 127, pp. 171- 178.
[12] Kwak, K. M., Torii, K., and Nishino, K., 2005, Simultaneous Heat Transfer Enhancement and Pressure Loss Reduction for Finned-Tube Bundles with the First or Two Transverse Rows of Built-In Winglets, Experimental Thermal and Fluid Science, Vol. 29, pp. 625-632.
[13] Chu, P., He, Y. L., and Tao, W. Q., Three-Dimensional Numerical Study of Flow and Heat Transfer Enhancement Using Vortex Generators in Fin-and-Tube Heat Exchangers," ASME Journal of Heat Transfer, Vol. 131, pp. 091903.
[14] Wang, C. C., Chang, Y. J., Wei, C. S., and Yang, B. C.,A Comparative Study of the Airside Performance of Winglet Vortex Generator and Wavy Fin-and-Tube Heat Exchangers, ASHRAE Transactions, Vol. 110, pp. 53–57.
[15] Chen, Y., Fiebig, M., and Mitra, N. K., Heat Transfer Enhancement of Finned Oval Tubes with Staggered Punched Longitudinal Vortex Generators, International Journal of Heat and Mass Transfer, Vol. 43, pp. 417-435.
[16] Elsherbini, A., and Jacobi, A. M.Th. Thermal-Hydraulic Impact of Delta-Wing Vortex Generators on the Performance of a Plain-Fin-and-Tube Heat Exchanger, HVAC&R Research, Vol. 8, pp. 357–370.
[17] Paul A. Sanders, Karen A. Thole, Effects of winglets to augment tube wall heat transfer in louvered fin heat exchangers International Journal of Heat and Mass Transfer 49 4058–4069
[18] Sommers, A. D., and Jacobi, A. M., Air-Side Heat Transfer Enhancement of a Refrigeration Evaporator Using Vortex Generation, International Journal of Refrigeration, Vol. 28, pp. 1006–1017.