Experimentation using delta winglet type vortex generator attached on tube surface of tube in tube heat exchanger for heat transfer augmentation

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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.

Keyword – *Delta vortex generator, attack angle, Rectangular shape, Triangular shape*

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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. Vortex generators are responsible for enhancement of heat transfer in tube in tube heat exchanger. [1] 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. 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. The study in this dissertation focuses on

vortex generators of different shapes which are welded on the inner surface of tube in tube heat exchanger for enhancement of heat transfer rate

2. Objectives

This work was taken in to consideration for improving heat transfer augmentation in tube in tube heat exchanger using delta winglet type vortex generators by changing geometrical change in to it. Thus use of delta winglet on surface of heat exchanger is to be done. The problem statement for project is to understand passive technique- delta winglet shape with geometrical modification like varying shapes and its effect on heat transfer augmentation for tube in tube heat exchanger.

In this experiment the following objectives have been set to find out effect on heat transfer augmentation by using various winglet shapes on the surface of tube in tube heat exchanger

1. To find out heat transfer coefficient and pressure drop using delta winglet type vortex generator in tube in tube heat exchanger.
2. To investigate the effect of Aspect ratio i.e. ratio of winglet base length and winglet height on heat transfer coefficient.
3. To investigate the effect of winglet shape i.e. Delta, triangular, rectangular and square on heat transfer coefficient.
4. To validate results with software simulation.

3. Experimentation

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.

Fig -1 Experimental setup

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 rate.

1. Calming Tube:

The Calming tube section is provided to allow the flow to be hydro-dynamically fully developed.

2. Venturimeter:

It is used to measure the mass flow rate, and thereby velocity of water. The Venturimeter is 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.

3. 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.

4. 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.

5. 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 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 consist of dimmer stat, temperature indicator and on-off switch.

Various winglet shapes are selected as per application of project. Following are the different types of winglet shapes are selected which are mounted on inside surface of tube heat exchanger for enhancement of heat transfer coefficient.

3.1 Vortex generator shape

1. Rectangular Shape

As shown in figure 2 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

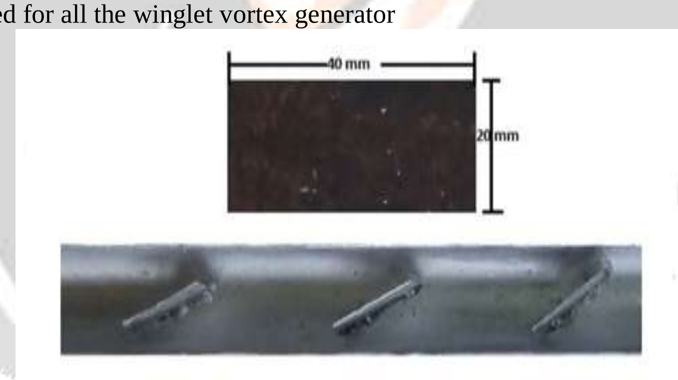

Fig -2 Rectangle shape

2. Square shape

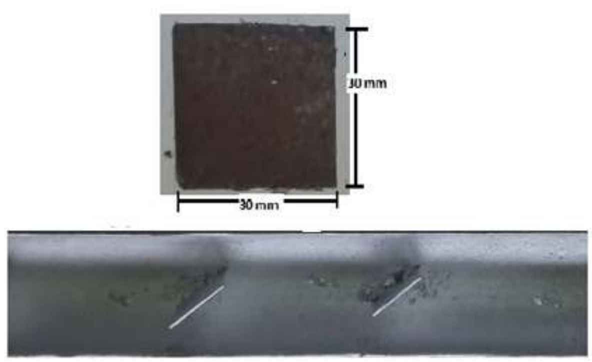

Fig -3 Square shape

As shown in figure 3 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.

3. Triangular shape

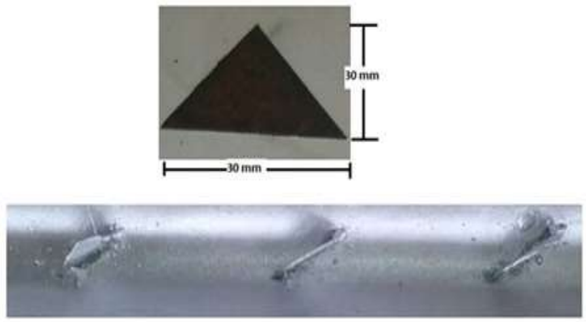

Fig -4 Triangular shape

As shown in figure 4 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.

4. Delta shape(D1) & Delta shape(D2)

As shown in figure 5 and 6 two delta winglet shapes are selected one with dimension 30 mm x 20 mm and one with 15 mm x 20 mm.

Fig -5 Delta shape (D1)

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.

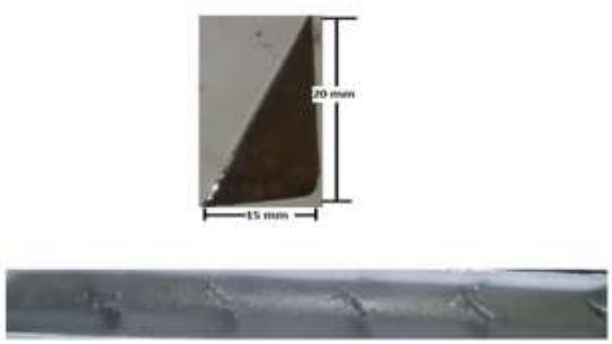

Fig -6 Delta shape (D2)

4. Result and discussion

From experimentation temperature readings are taken and heat transfer coefficient, Nusselt number and enhancement efficiency is calculated. Graph is plotted against Reynolds number and effect of Reynolds number on heat transfer coefficient, Nusselt number and enhancement efficiency is analyzed as follows

1. Effect of Reynolds Number on Heat Transfer Coefficient

Figure 7 shows the graph for heat transfer coefficient versus Reynolds number. From the figure 7 it is seen that heat transfer coefficient for Delta shape winglet type i.e. D2 has the highest heat transfer coefficient. Also heat transfer coefficient is going on decreasing as Delta winglet shape (D1), Rectangular winglet shape, triangular winglet shape and then square winglet shape respectively. Heat transfer coefficient in Delta winglet shape (D1) is increased 49% to 80 % as compared with smooth tube which is greater as compared with other winglet shapes.

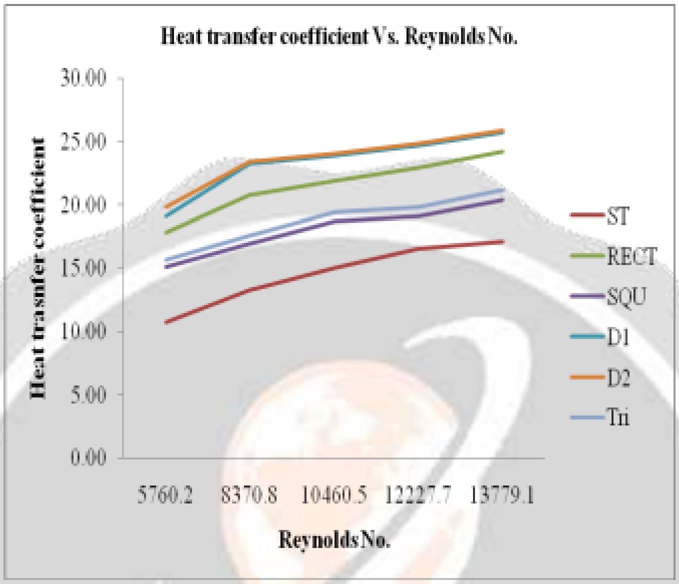

Fig -7 Effect of Reynolds Number on Heat Transfer Coefficient

Fig. 1.

2. Effect of Reynolds Number on Nusselt Number

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.5.1 and Figure. 8 respectively.

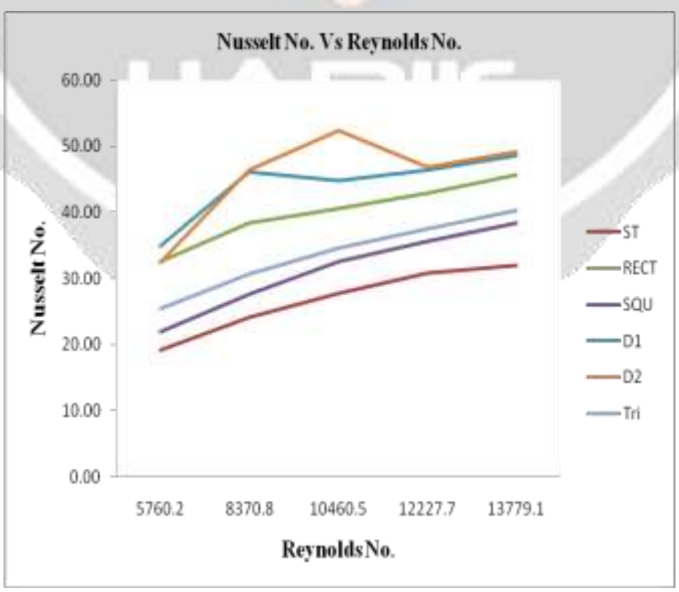

Fig -7 Effect of Reynolds Number on Nusselt Number

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 x 20mm 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. Effect of Reynolds Number on Pressure Drop

To evaluate the performance of heat exchanger with different type of winglet vortex generator values of enhancement efficiency versus Reynolds number are plotted in Figure 9. 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.

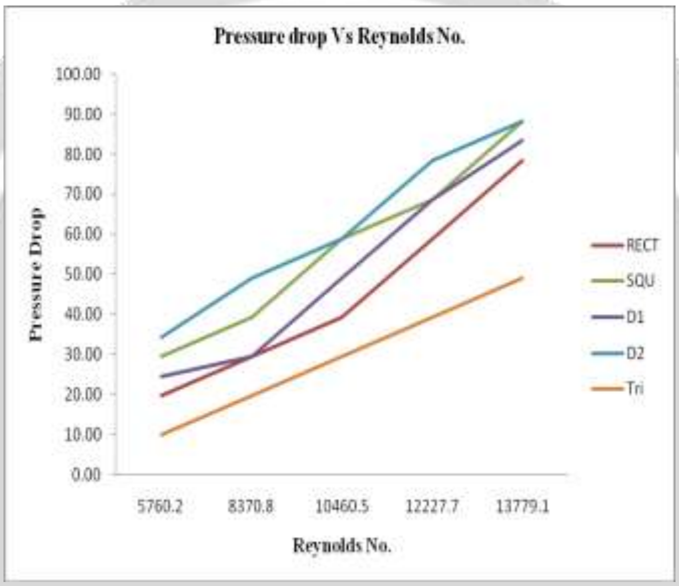

Fig -8 Effect of Reynolds Number on Nusselt Number

4. Effect of Reynolds Number on enhancement efficiency

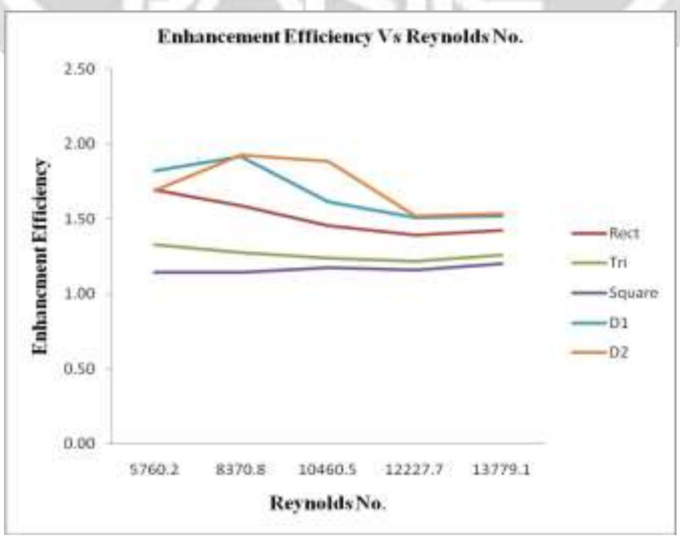

Fig -9 Effect of Reynolds Number on Enhancement Efficiency

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 10 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 drops Penalty is more for the square type winglet vortex generator this is 88.29 Pa at Reynolds number 13779.2

5. Variation of Experimental and software results

as show in figure 11 error is occurred in experimental and CFD heat transfer coefficients. Heat transfer coefficient increased as Reynolds number increases. Error in the heat transfer coefficient is occurred due to consideration of measurement of temperature uniformly in CFD analysis. While in actual experimental setup temperature sensors i.e. thermocouples are placed at one point and temperature measurement is taken at that point only.

Insert Type	Inlet Air Velocity	h (exp) (W/m2k)	h (CFD) (W/m2k)	%Error
Smooth Tube	2.32	10.33	10.73	3.73
Delta (D1)	2.32	19.06	20.12	5.27
Delta (D2)	2.32	19.80	21.43	7.61
Rectangular	2.32	17.83	18.36	2.89
Square	2.32	15.10	16.21	6.85
triangular	2.32	15.70	16.64	5.65

Table 1 Comparison of Experimental and CFD results

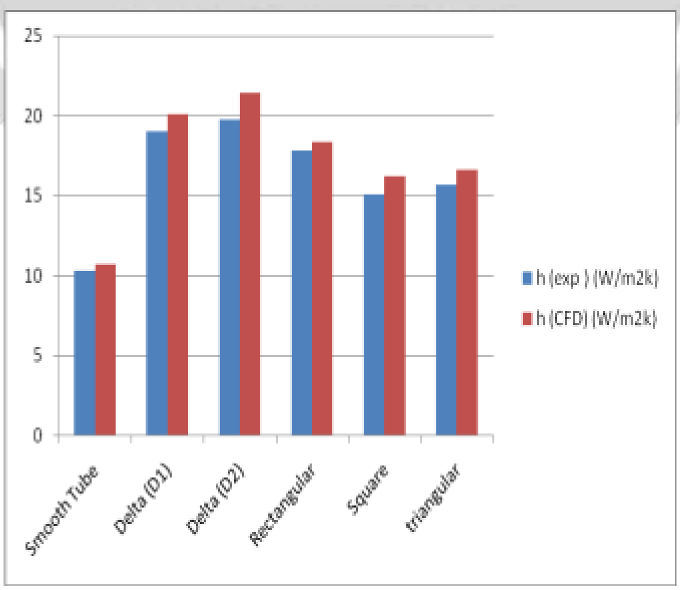

Fig -10 Comparison of experimental and CFD hea transfer coefficient

5. 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.

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