International Engineering Research Journal

# Experimental study of Curved delta wing Vortex Generator inserts in a circular tube for heat transfer enhancement.

***Pratiksha M. Age, Manish H. Attal.***
Mechanical Engg Dept, Sinhgad College of Engg , University of Pune, Pune, Maharashtra, India
Prof. Mechanical Engg Dept, Sinhgad College of Engg , University of Pune, Pune, Maharashtra, India

***Abstract***

*This work presents an experimental study on the heat transfer and friction factor analysis in smooth circular tube with Curved wing Vortex-Generator (VG) inserts. Temperature difference and pressure drop are measured and compared in two different steps of VG inserts, between input and output of circular tube, in the absence and presence of VG inserts in the turbulent flow with air as a working fluid. Here curved delta wing VGs were attached on opposite sides of a central rod at a specific location to form the insert. The thermal characteristic of these inserts are studied with varying different geometrical parameters of insert like pitch ratio(PR), angle of contact(α), number of insert(N). The heat transfer measurements for both cases, with and without VG inserts of the tube, are reported with reynolds number (Re) varying between 2000 and 14,000. Experimental results will be valided with CFD result and shows that heat transfer coefficient and friction coefficient increase with VG inserts than without VG inserts in circular tube.*

***Keywords:****Heat Transfer Enhancement, Curved delta wing vortex-generator, Turbulent flow.*

## 1. Introduction

Heat exchanger is very useful and so common device, which is used in heating and cooling system in various types of industries such as air conditioning, refrigeration system, power plant stations and chemical reactors. Therefore several techniques have been promotes to enhance heat transfer rate, decrease the size and cost of heat exchanger device. It is intended to transfer the desired amount of heat energy as quickly as possible.

The design procedure of heat exchangers is complex because it needs the analysis the heat transfer rate, pressure drop and efficiency. Therefore, the designers are always keen to develop the efficient and compact heat exchanger at lowest investment and running cost. In general, the methods of heat transfer enhancement are classified into three categories which are explained in details as below.

1.1 Active methods

In this active method of heat transfer enhancement, some external power input is used. Example of this method, in reciprocating plungers, used of magnetic field, surface vibration, fluid vibration, electrostatic field, suction or injection and jet impingement which needs external power supply for enhancement of heat transfer.

1.2 Passive method

In this method, surface and geometrical modifications which are applied to the flow passage and implementation of inserts or additional devices are used to augment the heat transfer rate. Inserts, also called as a swirls devices, treated surface, rough surfaces, extended surfaces and additives for fluids, are some examples of this method. Advantage of this method is that, no external power supply is required

1.3 Compound method

In this method, both active and passive methods are used. In other words, compound method is the combination of any two augmentations which is implemented at the same time like used of rough surface with twisted tape swirl flow device.

## 2. Literature Review

Various passive techniques have been found extremely effective in heat transfer enhancement of tube flow. Used of inserts is always praised due to its ability in enhancing the heat transfer rate by keeping the frictional losses in a workable limit. The literature work of this paper contained overall review on different types of inserts which is effectively played an important role in heat transfer applications. Used of any insert in any device as swirl generator and increase the fluid flowing time within system. So that maximum amount of heat energy is transferred. Watcharin Noothong and smith Eiamsa-ard [1], explained the effect of twisted taped insert in a concentric double pipe heat exchanger on heat transfer and fluid friction characteristic. They showed that, the maximum nusselt number by using this twisted tape insert with TR= 5 and 7 are 188% and 159% respectively higher than that plane tube. Chaitanya Vashistha and Anil Kumar Patil [2], used the multiple inserts arranged in co-swirls and counter-swirl orientation. These experimental data have been collected for single, twin and four twisted tape inserts. The maximum enhancement in heat transfer and friction are found to be 2.42 and 6.96 times that of smooth tube and maximum values of the thermo-hydraulic performance factor found to be 1.25 for a set of four counter-swirls twisted tape with the TR is 2.5. This experiment proved that, counter-swirls twisted tape inserts given better enhancement than co-swirls twisted tape. P. V. Durga Prasad and A. Gupta[3], they experimentally investigated the heat transfer enhancement using $Al_2O_3$/ water nanofluid in a U-tube with twisted tape inserts. In this worked, they varying the volume concentration of nanofluid of 0.001% and 0.03%, to analysis the heat transfer coefficient and corresponding friction factor. The nusselt number for 0.03 % of volume concentration of nanofluids with twisted tape inserts is enhanced by 31.28% and friction factor increased by 1.23 times compared to water of TRs of 5. A. Hasanpour and M. Farhadi [4], presented the paper on a review study on twisted tape inserts for turbulent flow characteristic. Here they found that twin counter-swirl and helical screw twisted tape, can reach the highest values of heat transfer rate. Smith Eiamsa-ard, P. Seemawute, [5], observed experimentally, the effect of peripheral cut of twisted tape on thermodynamic properties. This type of inserts is called as modified version of twisted tape. Here they take constant pitch and width of twisted tapes but varying peripheral-tape depth and width. This work concluded that, the higher the turbulence intensity of the fluids in vicinity of the tube wall generated by the peripheral-cut twisted tape compared to that induced by the typical twisted tape.

Taiwo O. Oni, Manosh C. Paul, [6], explained the numerical investigation of heat transfer and fluid flow of water through a circular tube induced with divers twisted tape insets. In this experiment, they modified the twisted tape like tube with elliptical cut twisted tape, circular cut twisted tape, triangular cut twisted tape, alternate-axis elliptical cut twisted tape, alternate-axis circular cut twisted tape and alternate-axis triangular cut twisted tape. Thermo-hydraulic performance of the flow system is affected by the shaped of cut on the twisted tape. From this work, they observed that, the tube with alternate-axis triangular cut twisted tape produced the best performance, having a thermal performance factor of 1.43. S. Pourahmad and S. M. Pesteei,[7], used the new type of inserts, wavy strip insert. They worked on effective-NTU analysis in a double tube heat exchanger equipped with wavy strip considering various angles were experimentally studied. Effectiveness-NTU analyses were made for the conditions with and without wavy strip inserts including their different anglesand compared to each other. It showed result that NTU and effectiveness have a maximum value at theminimum wavy strip angle $45^{\circ}$. P. W. Deshmukh, S. V. Prabhu and R. P. Vedula [8], studied the heat transfer enhancement for laminar flow in a circular tube using curved delta wing vortex generator inserts. In this research, the thermo hydraulic performance of these inserts with different geometrical parameters was studied. The average nusselt number ratio with and without insert, at equal reynold number is found to be in the range of 5.0 to 15.0.M. Khoshvaght-Aliabadi [9], studied on vortex-generator insert fitted in tabular heat exchangers with dilute Cu-water nanofluid as a working fluid. They experimentally studied vortex generator by changing four geometrical parameters such as winglets-pitch ratio winglets-length ratio winglets-width. It is found that the vortex generator inserts with lower winglets-pitch ratio and higher winglets-length / width ratios present higher values of heat transfer enhancement and pressure drop. Deshmukh and Vedula [10], explained the use of curved vortex generator inserts for heat transfer enhancement for flow through a tube in the turbulent flow regime. Curved delta wing shaped vortex generators were located close to the tube wall using a specially fabricated insert which provided a swirling motion of the fluid close to the wall. Arezuo Ghadi and Roja Parvizi Moghaddam [11], studied CFD Modelling of increase heat transfer in tubes by wire coil inserts. In this experiment, they has been studied the effect of improving heat transfer coils in heat exchanger in a laboratory by the method of computational fluid dynamics. Friction coefficient and nusselt number in the tubes with wire coils reduce with increase wire coil step.O. Sadeghi and H. Mohammed [12], studied heat transfer and nanofluid flow characteristics through a circular tube fitted with helical tape inserts by using finite volume numerical method. To enhance the heat transfer results, helical tape inserts is used with two different types of nanofluids, $Al_2O_3$ and $SiO_2$. By comparing two nanofluids $Al_2O_3$ nanofluid with cylindrical nanoparticle shape has the highest heat transfer enhancement and PEC compared to $SiO_2$ nanofluid.

A. A. Rabienataj Darzi, and Kurosh Sedighi [13], explained the experimental investigation of turbulent heat transfer and flow characteristics of $Sio_2$ / water nanofluid within helically corrugated tubes. Experiments were performed for plain tube and five roughened tube with various heights and pitches of corrugations. Results showed that adding the nanoparticle in the tube with high height and small pitch of corrugations augments the heat transfer significantly with negligible pressure drop penalty.A. Garcia, J. P. Solano and P. G. Vicente [14], studied the influence of artificial roughness shape on heat transfer enhancement. This work analyzes the thermal hydraulic behavior of three types of enhancement technique based on artificial roughness: corrugated tubes, dimpled tubes and wire coils. Heat transfer and pressure drop experimental data in laminar, transition and turbulent regimes are used in this investigation. This study concluded that for reynold numbers lower than 200, the used of smooth tubes is recommended. For reynold number higher 200 and 2000, the employment of wire coils is more advantageous, while for reynold number higher than 2000, the used of corrugated and dimpled tubes is favored over the wire coils because of the lower pressure drop encountered for similar heat transfer coefficient levels.A basic working of vortex generator inserts is presented in S. A. Wani work. S. A. Wani, S. R. Patil and A.P. Shrotri [15], explained a review of various shape vortex generator inserts like rectangular, trapezoidal and delta winglets. This work concluded that heat transfer rate with single and double rows of vortex generators have been observed and enhancement is found in double row.

## 3. Experimental set up and methodology

### 3.1 Experimental-Set up

Fig 1 show the schematic experimental set up diagram which is used in this work. The indication in set up diagram is explained in following table 1.

Table 1 Parts of Testing pipe

| Name of parts | Materials of parts | Geometrical configuration |
|---|---|---|
| 1 Outer pipe | Mild steel | ID= 38 mm, L= 1500, OD= 39 mm |
| 2 Central rod | Mild steel | D= 7 mm , L= 1500 |
| 3 VGs inserts | Mild steel (Sheet) | Thickness = 1 mm |

Fig 1 Experimental set up

Experimental set up consists of six major parts such as test section pipe with VG inserts, heating coils, electric blower, U-tube manometer, flow control valve and k-type thermocouple. Here air is used a working fluid with varying reynold number 2000 to 14000. The test section pipe was 1500 mm long mild steel material having uniform wall thickness 1 mm. The heating coil with insulation rope is wound around the test tube. Electric blower is attached at one end of test tube with flow control valve. There is 6 k-type thermocouple is attached around the test tube to measure the temperature at various locations and each one thermocouple is given at inlet and outlet of tube. Two ends of U-tube manometer is attached at inlet and outlet of test section. The geometric configuration of test section is shown in Table 1.

### 3.2 Geometrical details of Curved delta wing vortex generator inserts

The constructional details of the curved delta wing vortex generator (VG) insert that forms part ofthe insert used in the present study is shown if fig 2.

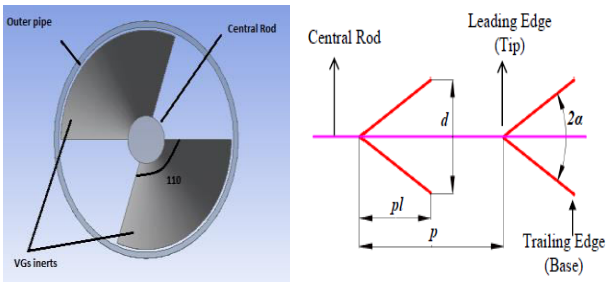


Fig 2 Front view and cross section of VG inserts

The curved delta wing vortex generator inserts is made from uniform mild steel sheet having uniform thickness 0.5 mm. The sheet is cut into flat triangular shapes with an included angle of attach α with a small extended portion, was bent over the surface of the cone to form the curved delta wing shaped vortex generator as shownfig 3.

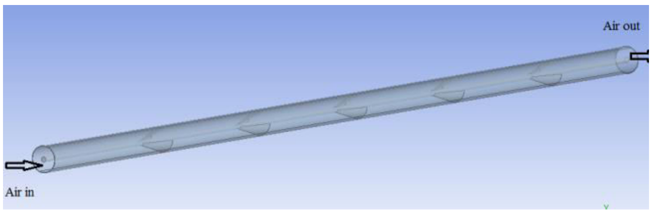


Fig 3 CAD model of VG insert with outer tube

### 3.3 CFD simulation

For this work, design model, pre-processing process was done. Fig 4 shows the meshing of inlet of test tube section.

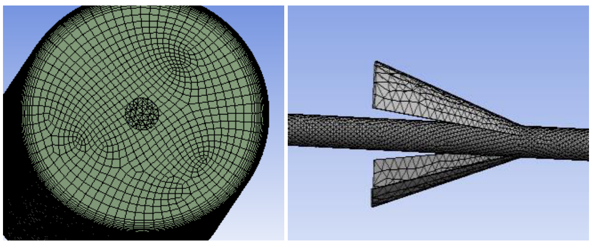

Fig 4 Meshed model

The mesh is used to construct finite volume, which are used to conserved mass, momentum and energy. In this work, the control volume is divided into 985765 elements. In meshing model, optimize meshing of present work is on processing.

## 4. Result and Discussion

The curved delta wing vortex generator inserts was examine by varying its geometrical parameter like angle of attach (α), number of inserts (N). The result obtained with VGs inserts was compared result obtained of without insert

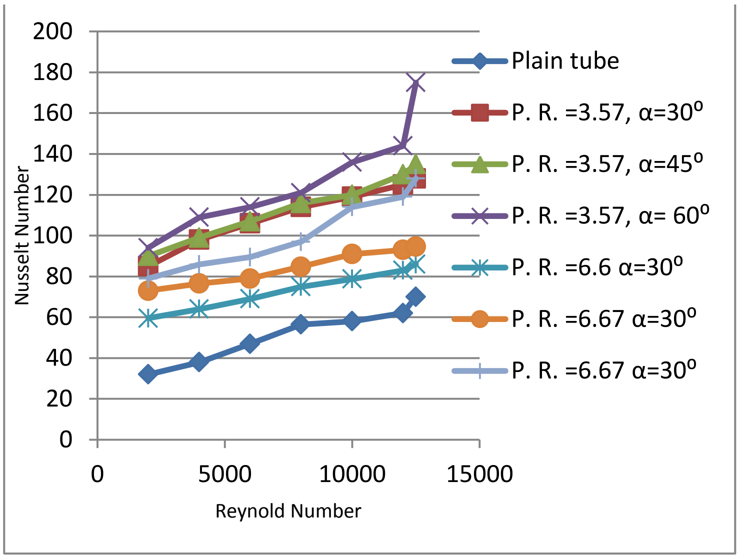


Fig 5 Variation of Nu Vs Re

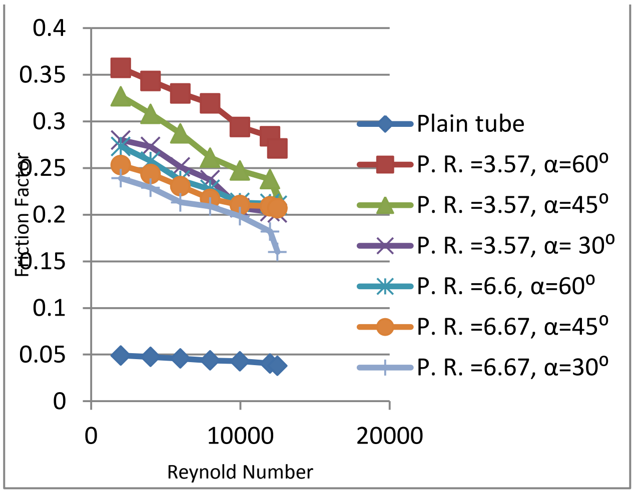


Fig 6 Variation of Friction factor Vs Re

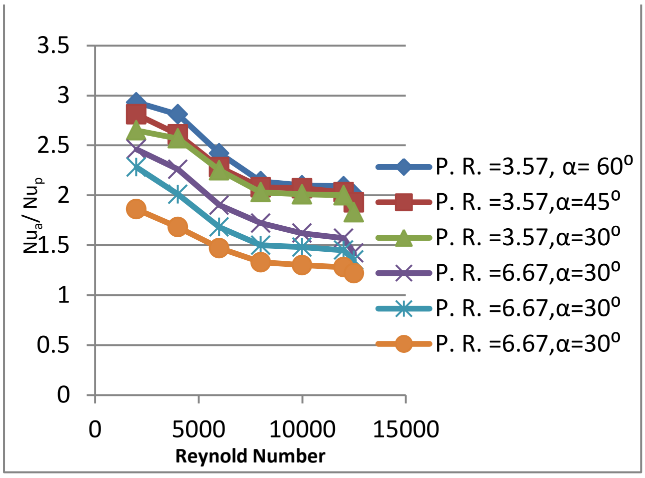


Fig 7 Nusselt number ratio Vs Re

## 5. Conclusion

From this experimental work, it shows that, curved delta wing vortex generator is a new design for heat transfer enhancement. These works conclude the following:

1. The average nusselt number ratio ($Nu_a$/ $Nu_p$), was varying from range 1.83 to 2.93 and 1.22 to 2.46 for pitch ratio 3.57 and 6.67 respectively.

2. Out of various angles of attack, angle $60^o$ shows the best performance based on nusselt number ratio.

3. The Nusselt number ratio, $Nu_a/Nu_p$increases with decrease in pitch ratio decreases.
4. Vortex generator (VG) inserts performs the better than the device used in literature work.

References

[1] Watcharin Noothong, Smith Eiamsa-ard and Pongjet Promvonge, Effect of Twisted tape Inserts on Heat transfer in a tube, The 2nd Joint International Conference on "Sustainable Energy and Environment (SEE 2006)", Bangkok, Thailand.

[2] Chaitanya Vashista, Anil Kumar Patil, Experimental Investigation of heat transfer and pressure drop in a circular tube with multiple insert, Applied thermal Engineering, 2005, pp 117-129.

[3] P. V. Durga Prasad, A. V. S. S. K. Gupta, Experimental investigation on enhancement of heat transfer using $Al_2O_3$ / water nanofluid in a U-Tube with twisted tape inserts, International communications in heat and mass transfer, (Article in press, ICHMT-03381; No of pages 8), 2016.

[4] A. Hasanpour, M. Farhadi and K. Sedighi, A review on twisted tape inserts on turbulent flow heat exchanger: The overall enhancement ratio criteria, International Communications in Heat and Mass Transfer, 2014, pp 2977-2987.

[5] S. Eiamsa-ard, P. Seemawute, K. Wongcharee, Influence of peripherally-cut twisted tape insert on heat transfer on heat transfer and thermal performance characteristics in laminar and turbulent tube flows, Experimental Thermal and Fluid science,34,2010, pp 711-719.

[6] Taiwo o. Oni, Manosh C. Paul, Numerical investigation of heat transfer fluid flow of water through a circular tube induces with divers tape insert, Applied Thermal Engineering (Accepted Manuscript, DOI http://dx.doi.org/doi: 10.1016/j.applthermaleng.2015.12.039.) , 2015.

[7] Saman Pourahmad, S. M. Pesteei, Effectiveness-NTU analysis in a double tube heat exchanger equipped with wavy strip considering various angles, Energy conservation and Management, 2016, pp 462-469.

[8] P. W. Deshmukh, S. V. Prabhu, R. P. Vedula, Heat transfer enhancement for laminar flow in tubes using Curved Delta Wing Vortex Generator inserts, Applied Thermal Engineering (Accepted Manuscript DOI http://dx.doi.org/10.1016/j.applthermaleng.2016.06.120), 8531, 2016.

[9] M. Khoshvaght-Aliabadi, M. H. Akbari, F. Hormozi, An empirical study on Vortex-Generator Inserts Fitted in Tabular Heat exchangers with Dilute Cu-Water nanofluid flow, Chinese journal of chemical engineering, (Accepted Manuscript, DOI 10.1016/j.cjche.2016.01.014 ), 480, 2015.

[10] P.W. Deshmukh, R. P. Vedula, Heat transfer and friction factor characteristics of turbulent flow through a circular tube fitted with Vortex generator insert, International journal of heat and mass transfer, 2014, pp 551-560.

[11] A. Ghadi, R. P. Moghaddam, M. T. Mazandarani, CFD Modelling of Increase Heat transfer in Tubes by Wire Coil Inserts, World Applied Sciences journal, 2012, pp 1443-1448.

[12] Omidreza Sadeghi, H. A. Mohammed, M. A. Wahid, Heat transfer and nanofluid characteristics through circular tube fitted with helical tape inserts, International communications in heat and mass transfer, (Article in press ICHMT-03305; No of pages 11), 2015.

[13] A. A. Rabienataj Darzi, Mousa Farhadi and Kurosh Sedighi, Experimental investigation of turbulent heat transfer and flow characteristics of $SiO_2$ / water nanofluid within helically corrugated tubes, International Communications in Heat and mass Transfer 39, 2012, pp 1425-1434.

[14] A. Garcia, J. P. Solano and P. G. Vicente, The influence of artificial roughness shape on heat transfer enhancement: Corrugated tubes, dimpled tubes and wire coils, Applied Thermal Engineering 35, 2012,pp 196-201.

[15] S. A. Wani, S. R. Patil and A. P. Shrotri, A review on effect of vortex generators on flow characteristics and heat transfer in heat exchanger, International journal of engineering science and research technology (ISSN : 2277-9655), 2015.