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# A REVIEW ON EFFECT OF VORTEX GENERATORS ON FLOW CHARACTERISTICS AND HEAT TRANSFER IN HEAT EXCHANGERS

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## ABSTRACT

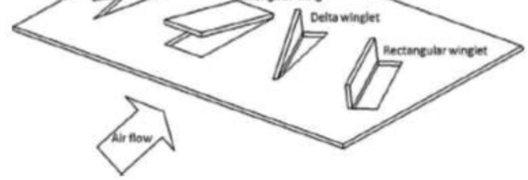
The development of high-performance thermal systems has increased interest in heat transfer enhancement techniques. The high thermal performance enhancement of heat exchanger systems is needed to use energy source efficiently due to the sky-rocketing prices of petroleum and coal fuels. Heat exchangers are widely used in industry both for cooling and heating. Insertion of turbulator in the flow passage is one of the favorable passive heat transfer augmentation techniques due to their advantages of easy fabrication, operation as well as low maintenance. The purpose of this experiment is to find the efficient shape and size of the vortex generator by using and comparing various types of Winglet pairs.

**KEYWORDS**: High-performance thermal systems, Heat Transfer, Vortex Generator, Winglet Pairs

## INTRODUCTION

A vortexgenerator (VG) is an aerodynamic device, consisting of a small vane usually attached to a lifting surface (or aerofoil), such as an aircraft wing or a rotor blade of a wind turbine. VGs may also be attached to some part of an aerodynamic vehicle such as an aircraft fuselage or a car. When the aerofoil or the body is in motion relative to the air, the VG creates a vortex, which, by removing some part of the slow-moving boundary layer in contact with the aerofoil surface, delays local flow separation and aerodynamic stalling, thereby improving the effectiveness of wings and control surfaces, such as flaps, elevators, ailerons, and rudders. Vortex generators are most often used to delay flow separation. To solve this problem, they are often placed on the external surfaces of vehicles and wind turbine blades. On both aircraft and wind turbine blades they are usually installed quite close to the leading edge of the aerofoil in order to maintain steady airflow over the control surfaces at the trailing edge. VGs are typically rectangular or triangular, about as tall as the local boundary layer, and run in span wise lines usually near the thickest part of the wing. They can be seen on the wings and vertical tails of many airliners.

Vortex generators are positioned obliquely so that they have an angle of attack with respect to the local airflow in order to create a tip vortex which draws energetic, rapidly moving outside air into the slow-moving boundary layer in contact with the surface. A turbulent boundary layer is less likely to separate than a laminar one, and is therefore desirable to ensure effectiveness of trailing-edge control surfaces. Vortex generators are used to trigger this transition. Other devices such as vortilons and various winglets, leading-edge extensions, leading edge cuffs, also delay flow separation at high angles of attack by re-energizing the boundary layer.



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Vortex generator is a kind of passive heat transfer enhancing device which are attached to the duct walls or fin surfaces and protrude into the flow at an angle of attack to the flow direction. The basic principle of vortex generators (VGs) is to induce secondary flow, particularly longitudinal vortices, which disturb or cut off the thermal boundary layer developed along the wall and remove the heat from the wall to the core of the flow by means of large-scale turbulence [1]. The earlier use of VGs on heat transfer enhancement (HTE) in literature may be reported by Johnson and Joubert [2] . They found that the air cooling effect of the cylinder surface was improved by using delta winglets. After that, many types of VGs have been investigated for enhancement of air-side heat transfer of thermal systems since the dominant thermal resistance is usually on the air-side for gaseliquid (or two-phase) heat exchangers. In addition to some specific VG shapes such as rods [3], bars, baffles, blocks and twisted tapes, most researches focused on wings and winglets which could be easily punched or mounted on the channel walls or fins and could effectively generate longitudinal vortices for high enhancement of convective heat transfer.

## LITERATURE REVIEW

S.M. Pesteei et al.[4] in the paper presented that local heat transfer coefficients were measured on fin-tube heat exchanger with winglets using a single heater of 2 inch diameter and five different positions of winglet type vortex generators. The measurements were made at Reynolds number about 2250. Flow losses were determined by measuring the static pressure drop in the system. Results showed a substantial increase in the heat transfer with winglet type vortex generators. It has been observed that average Nusselt number increases by about 46% while the local heat transfer coefficient improves by several times as compared to plain fin-tube heat exchanger.

Ya-Ling He et al. [5], investigated the heat transfer enhancement and pressure loss penalty for fin-and-tube heat exchangers with rectangular winglet pairs (RWPs) were numerically investigated in a relatively low Reynolds number flow. The purpose of this study was to explore the fundamental mechanism between the local flow structure and the heat transfer augmentation. The RWPs were placed with a special orientation for the purpose of enhancement of heat transfer. The numerical study involved three-dimensional flow and conjugate heat transfer in the computational domain, which was set up to model the entire flow channel in the air flow direction. The effects of attack angle of RWPs, row-number of RWPs and placement of RWPs on the heat transfer characteristics and flow structure were examined in detail. It was observed that the longitudinal vortices caused by RWPs and the impingement of RWPs-directed flow on the downstream tube were important reasons of heat transfer enhancement for fin-and-tube heat exchangers with RWPs.

Guobing Zhou et al. [6] , performance of a pair of new vortex generators e curved trapezoidal winglet (CTW) has been experimentally investigated and compared with traditional vortex generators e rectangular winglet, trapezoidal winglet and delta winglet using dimensionless factors e j/j0, f/f0 and R ¼ (j/j0)/(f/f0). The results showed that delta winglet pair is the best in laminar and transitional flow region, while curved trapezoidal winglet pair (CTWP) has the best thermohydraulic performance in fully turbulent region due to the streamlined configuration and then the low pressure drop, which indicates the advantages of using this kind of vortex generators for heat transfer enhancement. An appropriate spacing between the leading edges of a pair of CTW VG should be considered for different flow regions. In addition, double rows of CTWP do not show better thermohydraulic performance due to the larger pressure drop and the spacing between the two rows of CTWP should also be optimized.

J.M. Wua et al. [7] achieved heat transfer enhancement and lower pressure loss penalty, even reduction in pressure loss; two novel fin-tube surfaces with two rows of tubes in different diameters are presented in this paper. Numerical simulation results show that the fin-tube surface with first row tube in smaller size and second row tube in la+rger size can lead to an increase of heat transfer and decrease of pressure drop in comparison with the traditional fin-tube surface with two rows of tubes in the same size.

K. Torii et al. [8] proposed a novel technique that can augment heat transfer but nevertheless can reduce pressure-loss in a fin-tube heat exchanger with circular tubes in a relatively low Reynolds number flow, by deploying delta winglet-type vortex generators.

Feibig et al. [9] experimentally investigated the HTE and drag effect by delta and rectangular wings and winglets in laminar channel flow and found that the HTE per unit vortex generator area was highest for delta wings closely followed by delta winglets; rectangular wings and winglets were less effective; the average heat transfer was increased by more than 50% and the corresponding increase of drag coefficient was up to 45%.

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Further experiment with double rows of delta winglets in transitional channel flow by Tiggelbeck et al.[10] showed that the ratio of THE and drag increase was larger for higher Reynolds numbers. Experiments on VG in a water channel by Garimella and Eibeck [11] showed that HTE by a half delta wing increased with increasing Reynolds number in the laminar regime (up to 40%) but was lower in the turbulent regime, of the order of 5%.

Feibig [12] pointed out that the winglets are more effective than wings, but winglet form is of minor importance. With a dye-injection technique, Wang et al. [13] visualized the flow structure for enlarged plain fin-and-tube heat exchanger with annular and delta winglet vortex generators. They found that for the same winglet height, the delta winglet showed more intensive vertical motion and flow unsteadiness than annular winglet, however, the corresponding pressure drop of the delta winglet was lower than that of annular winglet.

Kim and Yang [14] experimentally investigated the flow and heat transfer characteristics of a pair of delta winglet VGs. They found that the common-flow-down arrangement of VGs better heat transfer characteristics than the common-flow-up cases. Joardar and Jacobi [15] studied the performance of winglet arrays in a full scale heat exchanger. They found that the winglets placed in common-flow-up orientation could improve the wake management with 220 < Re < 960.

Experimental work by Kwak et al. [16] also compared the performance of winglet Vortex generator with common-flow-up and common-flow-down configurations. Allison and Dally [17] presented an experimental analysis of the effects of delta winglets on the performance of a fin-and-flat tube radiator the winglets were arranged in common-flow-up configuration and placed directly upstream of the tube. The results showed that the winglet surface had 87% of the heat transfer capacity but only 53% of the pressure drop of the louvered-fin surface. Experimental results by Lawson and Thole [18] indicated that delta winglets placed on louvered fins produce augmentations in heat transfer as much as 47% with a corresponding increase of 19% in pressure loss

## SUMMARY OF REVIEW

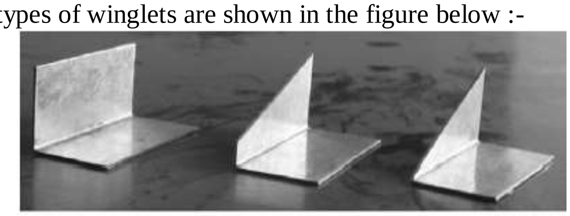
By referring to the above literature, it is observed that –

1. Heat transfer rate has been enhanced by using five different positions of winglet pairs of a particular surface.
2. Augmentation of Heat transfer is done by varying Reynolds number for flow.
3. Heat Transfer rate with single and double rows of vortex generators have been observed and enhancement is found in double row.

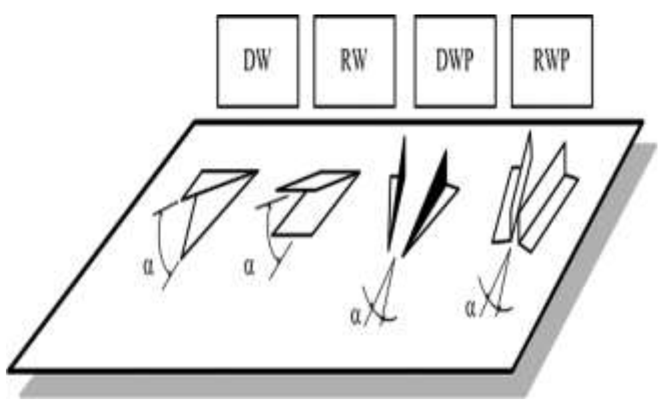
However, only little attention is given for study of combined effect of the above. Hence a good potential is there for carrying out an experimentation for finding the behavior of various types of winglet pairs under various operating conditions. The behavior will include the characteristics and heat transfer rates from various combinations. The winglet and winglet pairs will be used for increasing the area of heat transfer.

## PROPOSED WORK

An Experimental setup is proposed for finding out the thermal and flow characteristics of various types of winglet pairs which are vortex generators. The setup will consist a test section, which will include the actual vortex generators. The main aim of performing the test is to find the effective and efficient type of vortex generator. The test will be conducted by comparing the results of various types of winglet pairs. The various types of winglets are shown in the figure below :-



Rectangular winglet Trapezoidal winglet Delta winglet



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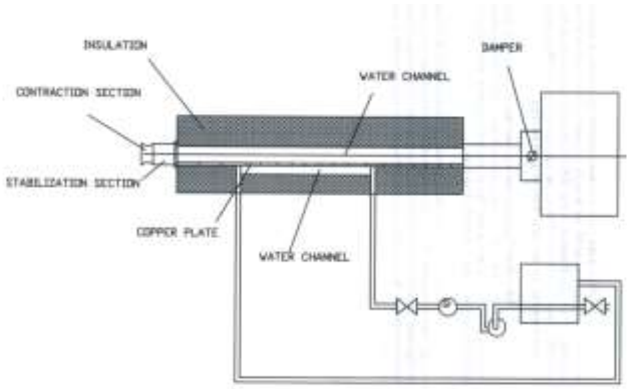


***Experimental Setup Diagram***

## CONCLUSION

It is concluded that the performance of heat exchangers will be enhanced by using various types of combinations of winglet and winglet pairs and also by varying the suitable parameter which will increase the heat transfer rate.

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