Experimental Analysis to Enhance Heat Transfer Rate by Using Semicircular Vortex Generator

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Abstract

An experimental work on heat transfer enhancement in a rectangular duct by inserting vortex generator in the form of semicircular winglets. These vortex generator mounted on flat surface with the help of riveting. Air as a test fluid flowed through duct at different Reynolds number (Re) in the range of 20000 to 100000 and test also conducted for free convection. The result is compared with semicircular vortex generator and without vortex generator in duct maximum increase in heat transfer rate is noted in free convection with vortex generator by (8.46%-37%) heat transfer coefficient increases by(25% - 43%).
The main purpose of this study is to show the performance of semicircular vortex generator to enhance heat transfer rate by increasing turbulancy of flow.

Keywords: *Heat transfer, High-performance thermal system, Thermal boundary layer, Vortex Generator, Winglets, Winglet pairs.*

I. Introduction:

One of the best methods to reduce boundary layer thickness is by the generation of passive vortices. In this technique the flow field is changed by an obstacle to generate a vortex which leads to reduction in the thermal boundary layer. Longitudinal vortices causes increase in heat transfer rate against small expense of the additional pressure loss. The sole effect of such vortices is an average increase in the heat transfer. Because the air-side thermal resistance is dominant, even modest enhancements in the air-side thermal-hydraulic performance could lead to smaller, lighter, and more energy efficient systems. Thus reason to use vortex generators is to generate secondary flow in the direction of fluid flow which could disturb the thermal boundary layer and extract the heat from the wall to the main streamline of the flow by generation of turbulence. Thus mechanism of flow reattachment and separation introduces a strong shear flow on the surface behind each vortex or winglet, which ultimately leads to an effective disruption of the thermal boundary layer and results to improvement of the heat transfer.
A vortex-generator (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.

Longitudinal Vortex Generator arrangement:

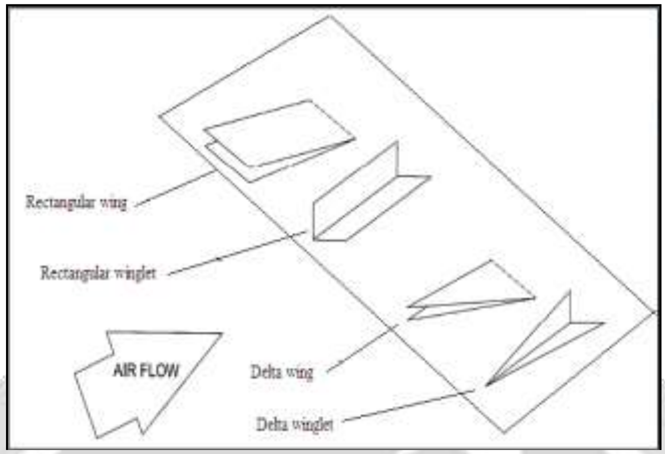

Fig.-1 Vortex Generator

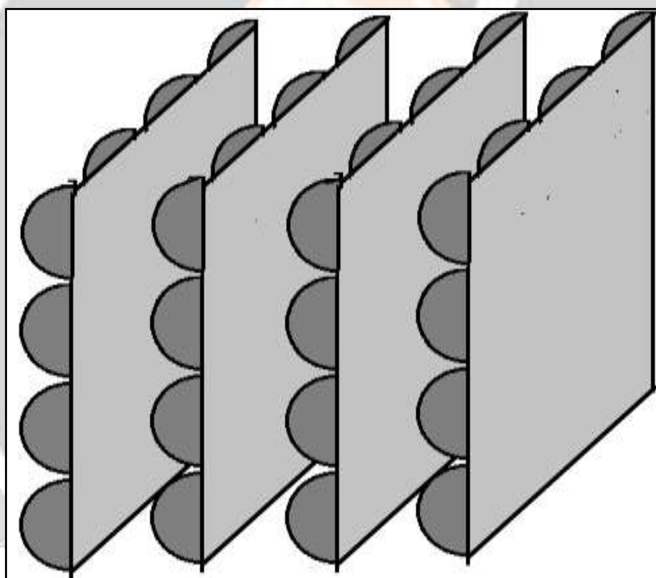

Fig.-2 Semicircular VG

II. Resources Used:

- Heater/Burner.
- Plates.
- Fan.
- Hollow Tube duct.
- Insulating Material.
- Air Inlet arrangement.
- Air Outlet arrangement.
- Temperature Detector Sensor.
- Switch Box.
- Regulator.
- Anemometer.

III. 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-andtube 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 threedimensional 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 RWPsdirected 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 lowtggtttzbn 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 d necrease of pressure drop in comparison with the traditional fintube 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.

IV. Experimental Arrangement

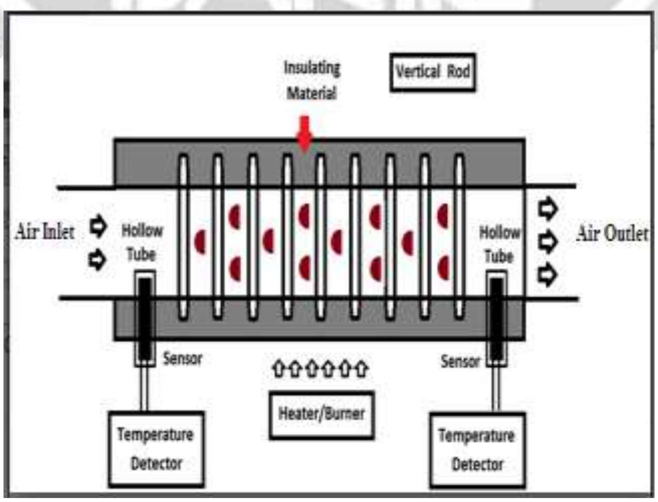

Fig.-3 Experimental Arrangement

Fig-4 Actual experimental duct with heater and fan

Fig-5 Semicircular vortex generator

V. Process:

1. Initially start fan and pass this air towards duct.
2. Hollow duct carries vortex arrangement; pass this air towards vortex unit.
3. Air which is to be passing through longitudinal vortex generator is heated by heater.
4. Finally hot air travelling through longitudinal vortex generator maximize heat transfer rate.
5. This hot air measured at the thermocouple as a temperature detector.
6. This process is repeated for different velocity and in free convection.
7. Then result is compared with vortex generator and without vortex generator for both the cases i. e. forced convection and free convection.

VI. Result and Discussion

With vortex generator

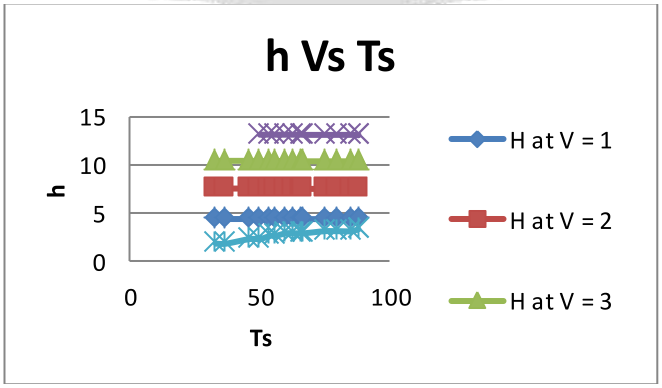

Chart-1 Variation in heat transfer coefficient with temp.

Without vortex generator

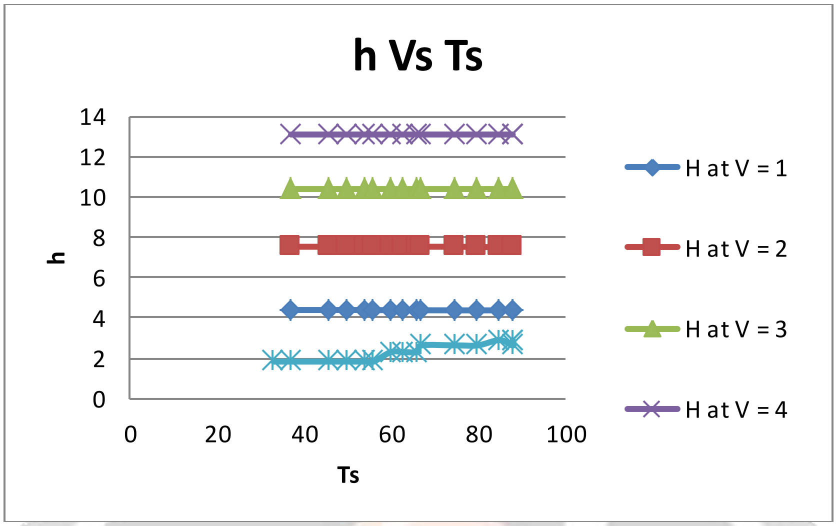

Chart-2 Variation in heat transfer coefficient with temp.

Fig. ( ) shows the behavior of heat transfer coefficient when velocity get increased as 1 m/s, 2 m/s, 3 m/s, 4 m/s and at free convection for different temperature i. e. with increasing temperature. It is observed that when velocity increases heat transfer rate also get increases for both the cases with and without vortex generator.

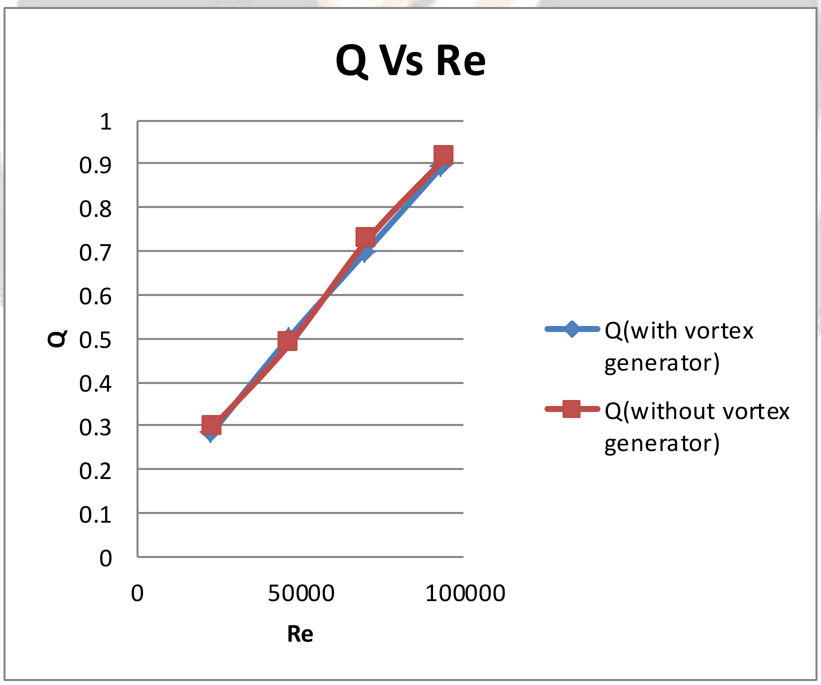

Chart-3 Variation in heat transfer rate with Reynolds number

The variation in heat transfer rate at different Reynolds number (20000 -100000) for semicircular vortex generator as a insert and without vortex generator. It is observed that increase in heat transfer rate is in variant rate and after inserting vortex generator we get constant increase in heat transfer rate. In forced convection vortex generator doesn't shows much result but its deflection is get constant.

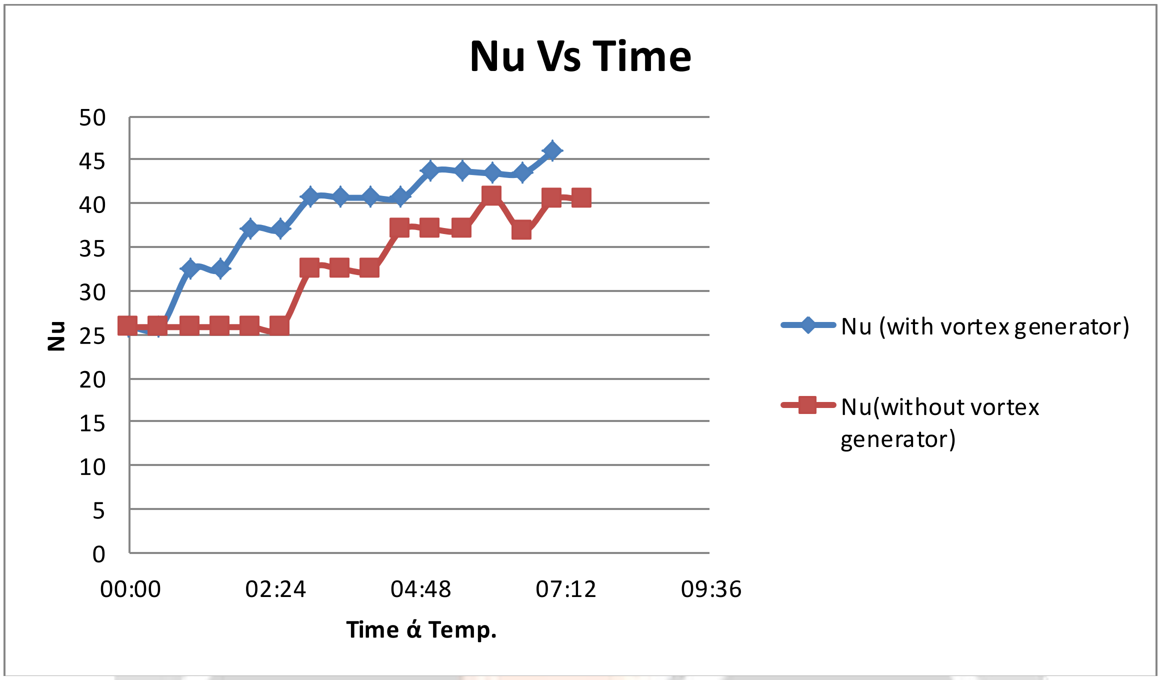

Chart-4 Variation in Nusselt number with temp.

Fig ( ) shows the relationship between nusselt number and time, here this time factor is related to temperature as time proceed heater is heated slowly so in the same condition with and without vortex generator nusselt number get increases with temperature, in both the cases and by inserting vortex generator nusselt number increases by 10% to 43%.

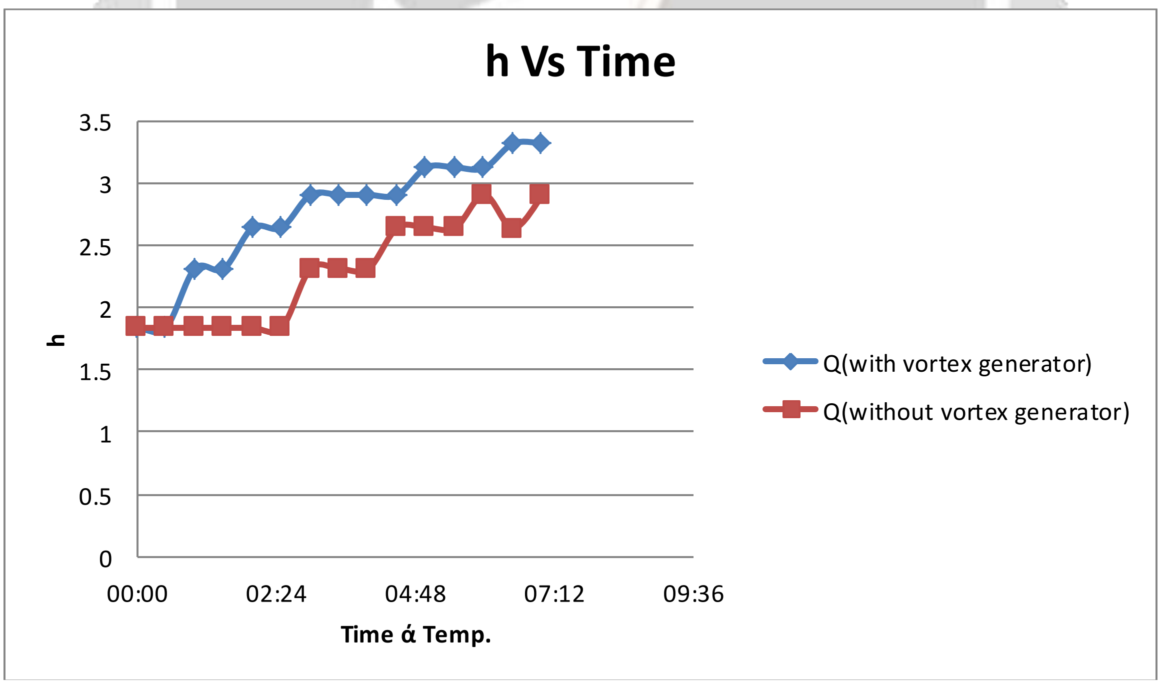

Chart-5 Variation in heat transfer coefficient with temp.

In fig ( ) it is observed that as time exceeded when heater is on heat transfer coefficient is get increase by (25% -43%) after inserting vortex generator in same manner heat transfer rate also get increase by (8.46%-37%) as shown in fig ( )

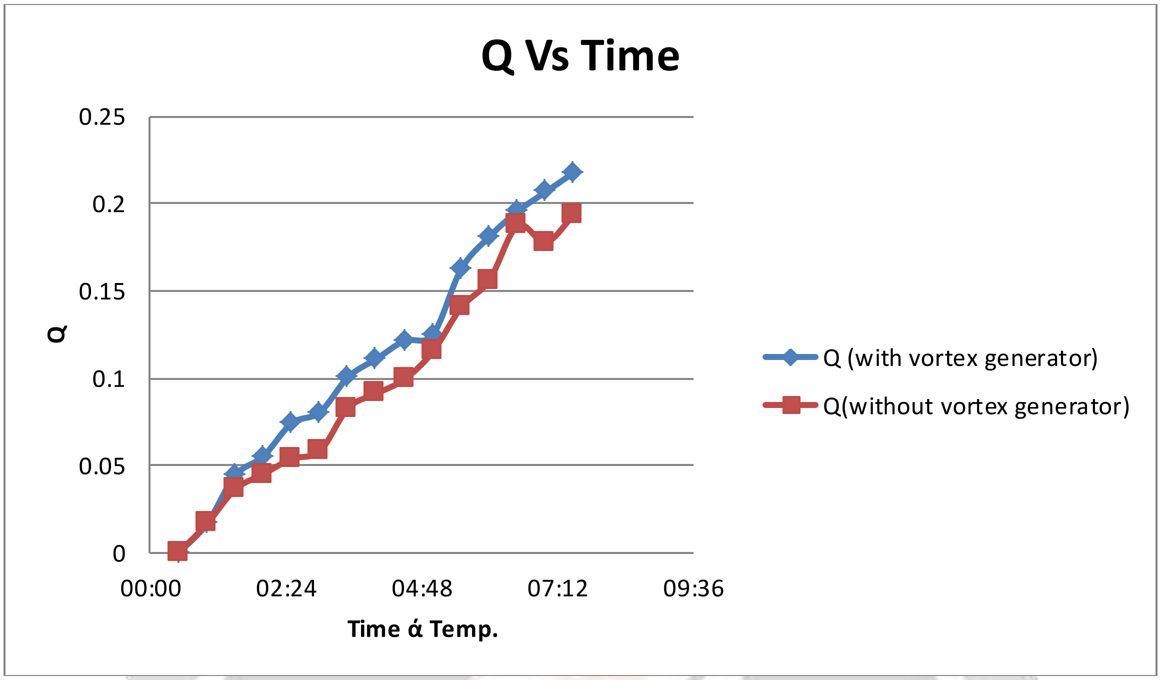

Chart-6 Variation in heat transfer rate with time

Conclusion:-

It is concluded that increasing in rate of heat transfer is observed 8.46%-37 % in free convection with semicircular vortex generator at different Reynolds number.

VII. Applications:

1. Airplanes.
2. Transportation.
3. Electronics Cooling and heating.
4. Refrigeration and evaporation assembly

VIII. References:

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