INVESTIGATION OF HEAT TRANSFER CHARACTERISTICS IN SEMI-CIRCULAR VORTEX GENERATOR IN INLINE AND STAGGERED ARRANGEMENT IN DIVERGENT CHANNEL

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Abstract - *The experimental and numerical results of trapezoidal channel provided with Semi-circular vortex generator on the flat plate for internal cooling are discussed. From the literature review conclude that the semi-circular vortex generator in inline arrangement has a high rate of heat transfer compared with other type of vortex generator. It is found that for the channel with inline arranged vortex generator, maximum heat transfer enhancement is attained. Staggered arrangement of the same vortex generator reduces pressure drop but also effects enhancement in heat transfer negatively. The thermal performance of the vortex generator size is an important parameter and its optimum value should be found out.*

Key Words: *Semi-circular Vortex generator, Heat Transfer rate, Performance evaluation factor.*

1. INTRODUCTION

The various techniques are used to enhance the rate of heat transfer over surface plate. It may be passive or active technique. The significant pressure drag produced by the rib or pin fin protrusion into the flow. The flow of heat transfer inside the channels has enhanced by using passive techniques such as rib tabulators, vortex, protrusions, fins, and dimples. Heat transfer enhancement techniques have practical application for internal cooling of turbine blades, internal combustion chamber liners and electronics cooling devices, biomedical devices and heat exchangers. The heat transfer can be increased by the following different Techniques.

1.1 Passive Techniques
1.2 Active Techniques
1.3 Compound Techniques.

1.1 Passive techniques

It is generally used for surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. It promotes higher heat transfer coefficients by disturbing or altering the existing flow performance (except for extended surfaces) which also leads to increase in the pressure drop. In case of extended surfaces, effective heat transfer coefficient on the side of the extended surface is increased. Advantages of passive techniques over the active techniques as they do not require any direct input of external power. In this techniques do not require any type of direct input of external power; rather than they use it from the system itself which ultimately leads to an increase in fluid pressure drop.

1.2 Active techniques

According to design point of view and usable these techniques are more complex and it requires some external input power to cause the desired flow modification and improvement in the rate of heat transfer. These techniques have limited application because of the need of external power in many practical applications. In comparison to the passive techniques, these techniques have not shown many possibilities as it is very tough to provide external power in many cases.

1.3 Compound Techniques

In this techniques one or more than one of the above mentioned techniques are used in combination for the purpose of improving the thermo-hydraulic performance of a heat exchanger. This technique involves complex design and hence has limited applications.

2. LITERATURE REVIEW

[1] Charbel Habchi, Serge Russeil, et al. they have studied Global and local analysis of the heat transfer in turbulent vertical flows is studied using three-dimensional numerical simulations. Vorticity is generated by inclined vortex generators in a turbulent circular pipe flow with twelve different configurations that fall into three categories.

[2]Li Li, Xiaoze, they studied about Fin-and-tube heat exchangers with longitudinal vortex, plain fins are widely used in direct air-cooled condenser system in the power plant, because of its relatively simple property compared to some other fins with variable cross-sectional area channel.

[3]Azitaabdollahi, Prof. Mehrzad Shams had studied a three dimensional numerical investigation of the fluid flow and heat transfer behavior of longitudinal vortex generator (LVG) has been carried out in a rectangular micro heat sink in the Reynolds number range between 200 and 1100 in the temperature range without involving phase change. These findings have important bearing on achieving enhanced cooling performance for small electronic devices not involving any complicated geometric arrangement.

[4]**P.W. Deshmukh, S.V. Prabhu, et.al,** they did experimentation for evaluating heat transfer enhancement in a circular tube fitted with a curved delta wing vortex generator insert are presented. The average Nusselt number ratio with and without the insert (Nua/Nus), at equal Reynolds number (Re) was found to be in the range of 5.0 to 15.0. The performance ratio R3, (Nua/Nuc), based on equal pumping power and constant heat transfer area, was found to be in the range of 1.0 to 6.0.

[5]Mohammad Oneissi, Charbel Habchi, et.al, has been studied heat transfer is a naturally occurring phenomenon that can be greatly enhanced with the aid of vortex generators (VG). Three-dimensional numerical simulations of longitudinal vortex generators were performed to analyze heat transfer enhancement in parallel plate-fin heat exchanger. This study highlights the different mechanisms involved in the convective heat transfer intensification by generating more vortices using more aerodynamic VG shape while decreasing the pressure drop penalty.

[6]Anupam Sinha, Himadri Chattopadhyay, et al, had studied that simulates the air flow through fin-tube type heat exchangers with rectangular winglet pairs (RWP) of half the channel height as vortex generators (VG). They studied the in-line row of tubes, whereas with the staggered row of tubes, there was slight deviation of this trend. Due to the alternate CFD–CFU orientations of the VG, the performance improves with increase in angle of attack up to a certain point and afterwards it was going down.

[7] KeWei Song, WanLing Hu, et.al, they have studied on secondary flow intensity and heat transfer intensity in flat-tube-and-fin air heat exchanger with vortex generators. There was no corresponding relationship neither between Nu and Re nor between f and Re.

[8]**R.K. Ali,** they have investigated experimental effect of rectangular winglet vortex generators on thermal performance of square flat heat source near a wake region. Rectangular winglets were fixed on the base board with common inflow orientation to direct the flow toward the core of stagnation zone.

[9]A. Esmaeilzadeh, N. Amanifard, et.al. They have studied comparison of simple and curved trapezoidal longitudinal vortex generators for optimum flow characteristics and heat transfer augmentation in a heat exchanger is studied. Numerical results showed that CTWP has a lower pressure drop and a better overall performance compared to TWP. To achieve a maximum heat transfer augmentation and a minimum pressure drop, optimal height and clearance between two vortex generators had been determined by using and combining computational fluid dynamics analysis, artificial neural networks and single-objective genetic algorithm.

[10]Ralph Kristoffer B. Gallegosa, et.al, They perform flag vortex generators for thermal enhancement and the use of flexible plates or “flags” as vortex generators inside a channel was successfully demonstrated as an alternative heat transfer enhancement technique. This paper is a brief review of flag vortex generators for thermal enhancement. Extensive and intensive experimental results were lacking to validate numerical and theoretical predictions.

[11]S.A. Isaev, A.V. Schelchkov, et.al, Worked on Vortex heat transfer enhancement in the narrow plane-parallel channel with the oval-trench dimple of fixed depth and spot area paper present. The article was devoted to the analysis of vortex heat transfer enhancement due to the use of oval-trench dimples. In this case, moderate hydraulic losses in the channel with an oval-trench dimple, when its length is increased to 6.78, were comparable to those in the channel with a basic spherical dimple.

[12]Hung-Yi Li, Wan-Rong Liao, et.al, They check the thermal-fluid characteristics of a pin-fin heat sink with delta winglet vortex generators in a cross flow are investigated experimentally and numerically. The thermal resistance of the heat sink with the vortex generators arranged in the common-flow-up configuration was lower than that of the heat sink with the vortex generators arranged in the common-flow-down configuration.

[13]Lei Luo, Fengbo Wen, et.al, In this study, effects of dimples and their arrangement on the flow structure, heat transfer and friction factor in a solar receiver heated channel with delta-winglet vortex generators (DWVGs) were numerically studied. The thermal performance analysis indicates that the use of dimples increases the thermal performance by 28.50%. It was also found that the adoption of inline dimples contributes to the optimal thermal performance and mixing of the cold and hot fluid.

[14]J. Ortega-Casanova, F. Molina-Gonzalez The consequences of installing one or two vortex generators on a flat plate under axisymmetric conditions were presented in the work in order to analyze if heat transfer from the plate can be enhanced. The averaged heat transfer on the tabbed plate can

3. PROBLEM STATEMENT

Experimental and Numerical investigation of heat transfer enhancement through Inline and Staggered vortex generator for divergent Channel.

4. OBJECTIVES OF THE STUDY

a. To perform heat transfer enhancement analysis in semi-circular vortex generator.
b. To conduct the experimental study on semi-circular vortex generator for different parameters of performance (E.g. Nusselt Number, Arrangement of Geometry, Pressure drop & PEF etc)

5. CFD SIMULATION

Work Requirements:
Trapezoidal Aluminum Plates- 13X27X500 mm
Height- 10mm

Boundary Conditions:

Inlet: Velocity inlet 1, 1.5, 2
Outlet: Pressure Outlet 0 gauge Pressure
Source: Constant Heat Flux
Meshing:
Tetra hedral mesh has used for simulation

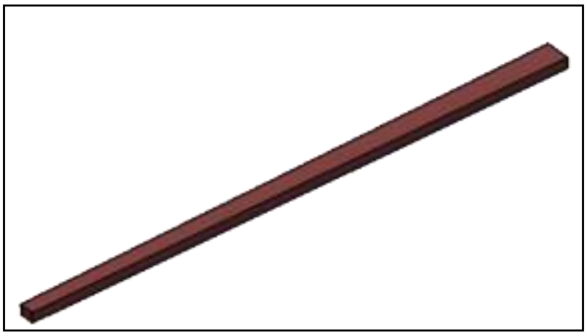


Fig.1. Shows Flat aluminum plate.

Fig.2. shows Inline arrangement of semi-circular vortex generator.

Fig.3.shows staggered arrangement of semi-circular vortex generator.

Fig no. 1, 2 and 3 shows geometry of flat, inline and staggered vortex generator which will used for CFD simulation and experimentation.

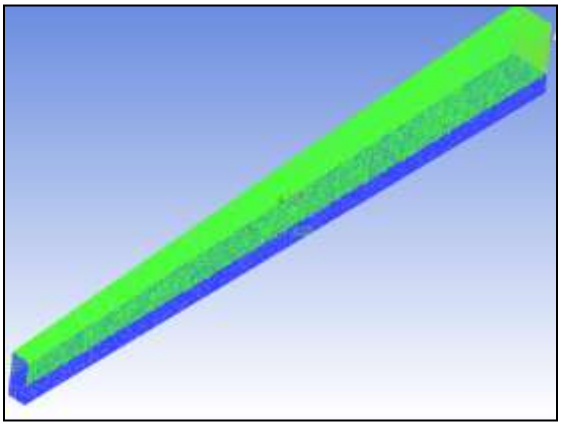


Fig.4.shows Shows Meshing of Flat aluminum plate.

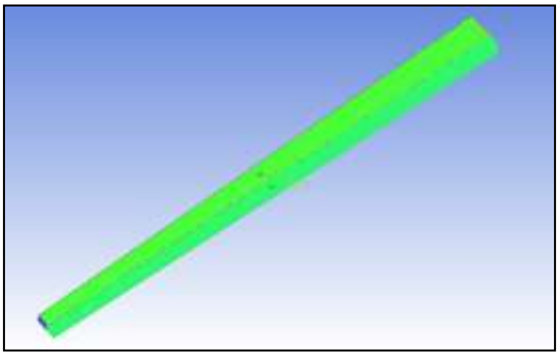


Fig.5.shows Meshing ofInline arrangement of semi-circular vortex generator.

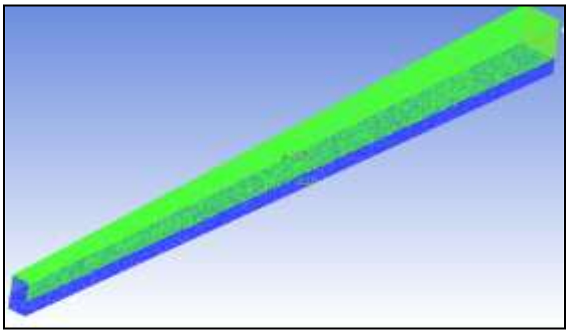


Fig.6.shows meshing of staggered arrangement of semi-circular vortex generator.

Fig. no. 4, 5 and 6 shows tetra hedral meshing of flat, inline and staggered vortex generator respectively.

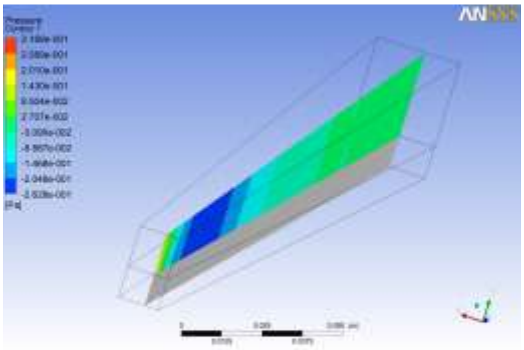


Fig7. Shows Pressure drop of flat plate at velocity 2 mps

Fig. no. 7, 8 and 9 shows pressure variation, temperature distribution and velocity profile of flat plate with velocity 2 m/s respectively.

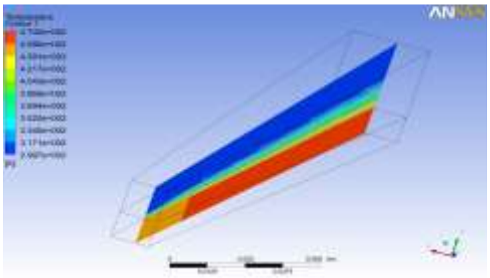


Fig.8. Shows Temperature reduced on flatplate at velocity 2mps

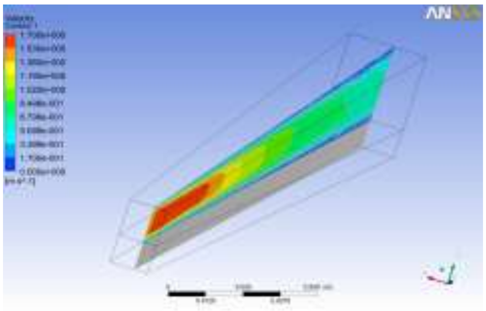


Fig.9. Velocity_flatplate_gsf7_V2 mps

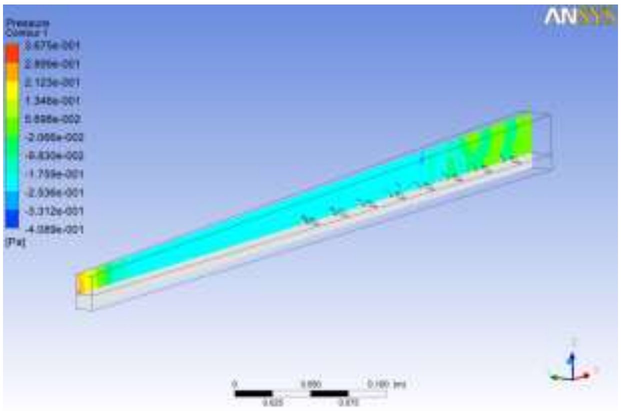


Fig.10. Shows Pressure dropinline VG AS1.5 V2mps

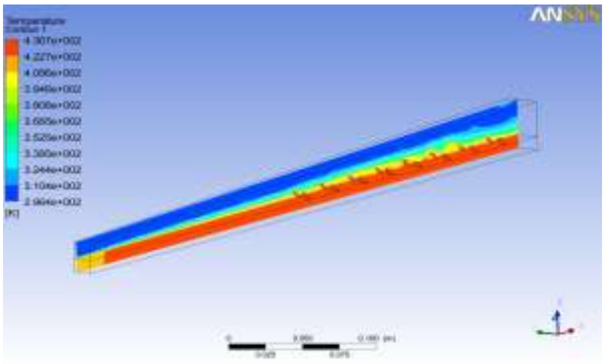


Fig.11.Shows Temperature reduced inline VG AS1.5 V2 mps

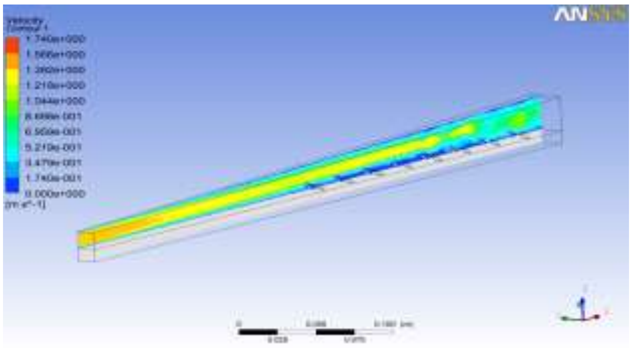


Fig.12.Velocity counters inline VG AS1.5 V2 mps

Fig. no. 10, 11 and 12 shows pressure variation, temperature distribution and velocity profile of inline plate with velocity 2 m/s respectively.

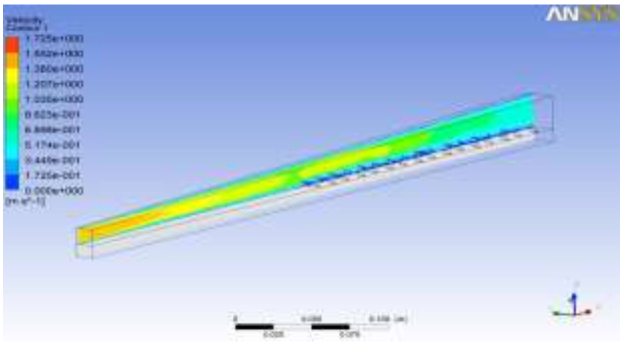


Fig.13.Velocity CountersStaggered VG AR1.5 vel 2mps

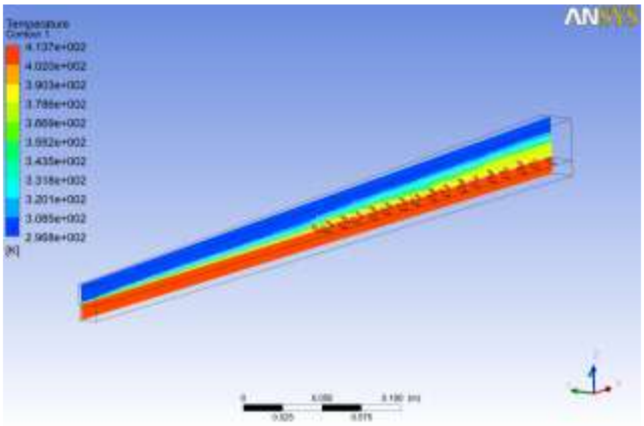


Fig.14.TemperatureCounters Staggered VG AR1.5vel 2 mps

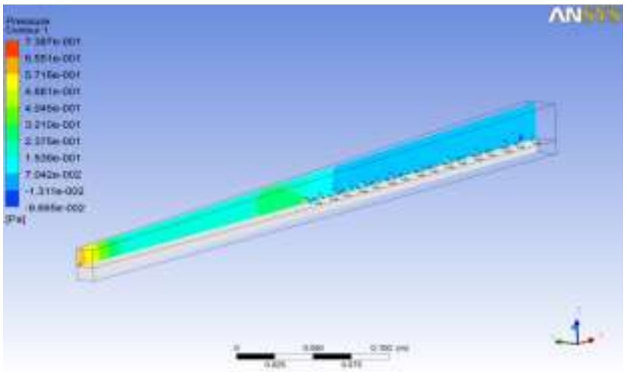


Fig.15.Pressure CountersStaggered VG AR1.5vel2 mps

Fig. no. 13, 14 and 15 shows pressure variation, temperature distribution and velocity profile of staggered plate with velocity 2 m/s respectively.

4. CALCULATION STEPS

1 Heat absorbed by air: $Q = mcp\Delta T$ (1)

Where, m is mass flow rate of air

cpis heat carrying capacity rate of air

$\Delta T$is change in temperature of air (To- Ti)

2 Heat transfer by convection $Q= hA\Delta T$ (2)

Where,

h is heat transfer coefficient of air

A is surface area of test plate

$\Delta T$is change in temperature of (Tw-Tf)

3 $Nu= hD/Kf$ (3)

Where,

K_f is thermal conductivity of air

4 Enhancement ratio = NuVG/ Nuflat (4)

5 Performance Enhancement Factor = (NuVG/ Nuflat) / (ΔPVG/ ΔPflat)1/3 (5)

5. EXPERIMENTATION

To investigate the performance of vortex generator on the several configurations with different angle of attacks were investigated. The angles of attack of vortex generator with the rectangular plate were 300, 450, 600 and 900 to the Inline as well as Staggered vortex generator, considering the velocity 1, 1.5, and 2 m/s, and corresponding Reynold's no 1250, 1875and 2500. The experimental setup is as shown in fig 16. Following are the components of experimentation.

a) Blower

b) Temperature sensors & indicators

c) Voltmeter and ammeter

d) Strip Heater

e) Velocity measuring instruments-Hot wire Anemometer

f) Trapezoidal Aluminum Plate (test section) -13X27X500 mm is shown in figure

Fig.16.Experimental Set up.

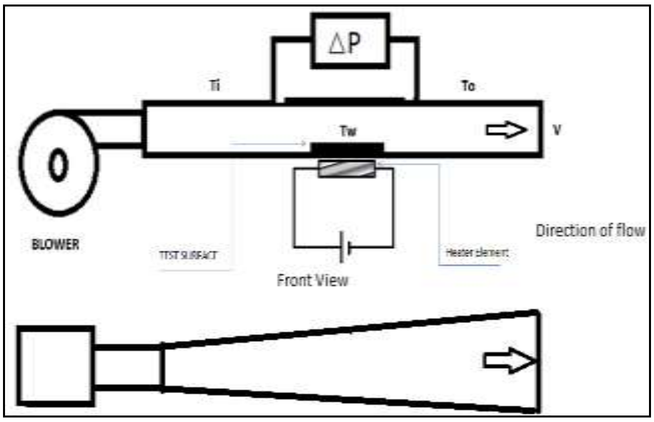


Fig. 17.Shows Block Diagram of Set up.

Fig. no. 16 and 17 shows the experimental set up and the block diagram of the project.

Fig. no. 18, 19 and 20 shows the flat aluminum plate, inline arrangement of vortex generator and staggered arrangement of vortex generator respectively.

Fig.18.Flat Alluminum Plate.

Fig.19.Alluminum Plate with vortex generator in inline arrangement.

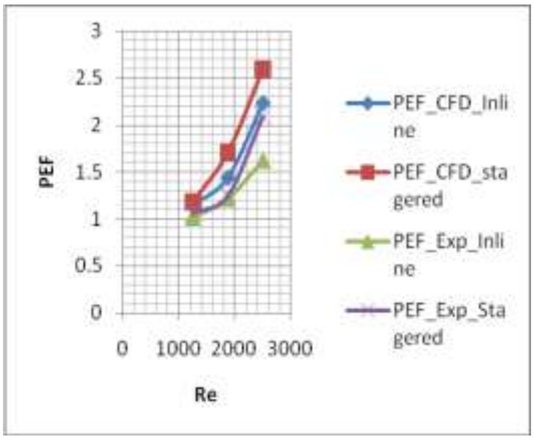
Fig.20.Alluminum Plate with vortex generator in inline arrangement.

CFD simulation was carried out first to see the effect of Reynolds number over different plate such as flate, inline and staggered vortex generator.

Table 1.Comparison of performance evaluation factor with experimental and analytical method

Re	PEF_CFD_ Inline	PEF_CFD_ stagered	PEF_Exp _Inline	PEF_Exp _Stagered
1250	1.14878	1.178807	1.014923	1.059221
1875	1.443311	1.709541	1.21538	1.243358
2500	2.231334	2.595477	1.62164	2.092109

Table no.1 shows the analytical and experimental comparison of performance evaluation factor which shows that the staggered arrangement of vortex generator has the good result compared with the inline vortex generator. And graph 1 is the result of table 1.

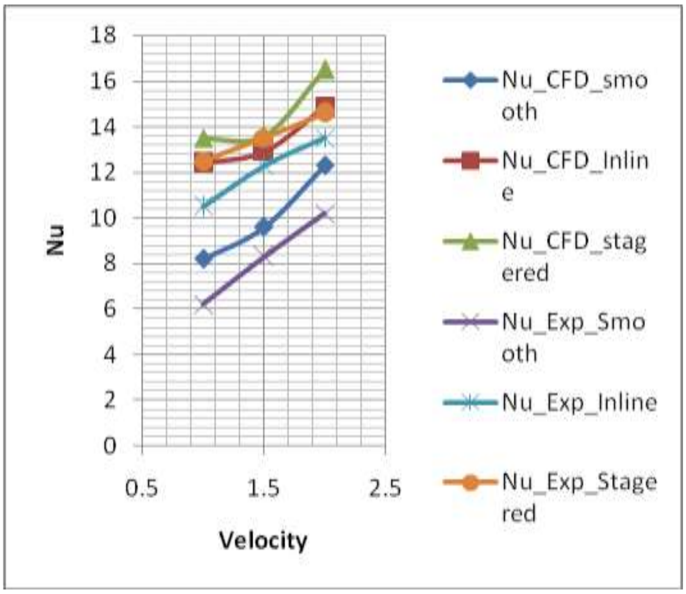


Graph 1. Performance evaluation factor.**Table 2.**Comparison of Nu with experimental and analytical method.

Plate Type	Vel	CFD	Exp
Smooth	1	8.2	6.2
	1.5	9.6	8.3
	2	12.3	10.2
Inline	1	12.4	10.5
	1.5	12.92	12.3
	2	14.84	13.5
Staggered	1	13.5	12.5
	1.5	13.6	13.5
	2	16.5	14.6

Graph no.2 shows the analytical and experimental comparison of Nusselt no. which is also shows that the staggered arrangement of vortex generator has the good result compared with the inline vortex generator. And graph 2 is the result of table 2.

Staggered arrangement of the same vortex generator reduces pressure drop. In staggered arrangement of vortex generator the flow pattern of air changed because of vortex arrangement mounted on the plate so we get the good result of heat transfer rate.



Graph 2. Nu vs. velocity

6. CONCLUSION

The heat transfer performance and pressure drop of semi-circular vortex generator to the inline and staggered arrangement with different velocities are studied, On the basis of experimental analysis and Numerical analysis. It is conclude that the heat transfer rate of semi-circular vortex generator in inline arrangement is better. Getting the good results of experimental and Numerical values of Nusselt's no for the staggered vortex generator at velocity 2 m/s is 14.6 and 16.5 respectively.

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