Experimental Investigation of Heat Transfer Enhancement through Curved Wing Delta Generator

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Abstract- *The efficiency of energy converters, cooling units and heat exchangers is the most important aspect for their economical success. For heat transfer enhancement in micro heat exchangers most often passive devices like roughness elements, dimples or cavities are used. For conventional converter heat exchange is enhanced by modifying the flow with bigger scale control devices like e.g. guiding plates, diverter strakes or delta shaped wings can be found. The main physical mechanisms causing the enhancement of heat transfer is the generation and amplification of sufficiently strong longitudinal vortices which are interacting with the thermal boundary layer.*

The convection of warmer fluid perpendicular to the heated wall and the mixing with colder fluid is intensified, and, additionally, further external momentum is transported into the inner boundary layer region. Depending on the specific technical application, flow control experimentally the flow effects of fins and wings to improve the heat transfer on plates and in tubes or channels. They also conducted numerical simulations considering flow control devices with varying shape and geometry to find device design criteria for heat transfer enhancement. Since vortex induced heat transfer enhancement depends strongly on shape and position of vortex generators the subject of ongoing research is to find design strategies for device shape and placement optimization. In particular, the investigation of confined channel flows with delta wing vortex generators has motivated numerous numerical and experimental studies. Until now the physical mechanisms are not sufficiently understood. Thus, in order to improve the design of compact heat exchangers a better physical understanding of the generation of these flow structures is mandatory. Therefore, the task of the presented work is to analyze Experimental setup consist of divergent test channel in which aluminum plates are kept on which curved delta wing vortex generator are pinched with different aspect ratio(1,2), arrangement (Inline, staggered) on which forced convection heat transfer will perform with Reynolds number in the range 5000 to 10000.

Results are to be investigated on increase in heat transfer coefficient (h), Nusselt number (Nu), pressure drop (Dp)and thermal performance (Tp) in different arrangement of curved delta wing votex generator

Mention the abstract for the article. An abstract is a brief summary of a research article, thesis, review, conference proceeding or any in-depth analysis of a particular subject or discipline, and is often used to help the reader quickly ascertain the paper's purpose. When used, an abstract always appears at the beginning of a manuscript, acting as the point-of-entry for any given scientific paper or patent application.

I. INTRODUCTION

Heat transfer inside flow passages can be enhanced by using passive surface modifications such as rib tabulators, protrusions, pin fins, and dimples. These heat transfer enhancement techniques have practical. Application for internal cooling of turbine airfoils, combustion chamber liners and electronics cooling devices, biomedical devices and heat exchangers. The heat transfer can be increased by the following different Augmentation Techniques. They are broadly classified into three different categories: (i) Passive Techniques (ii) Active Techniques (iii) Compound Techniques.

1.1 Passive techniques

These techniques generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. They promote higher heat transfer coefficients by disturbing or altering the existing flow behavior

1.2 Active techniques

These techniques are more complex from the use and design point of view as the method requires some external power input to cause the desired flow modification and improvement in the rate of heat transfer. It finds limited application because of the need of external power in many practical applications. In comparison to the passive techniques, these techniques have not shown much potential as it is difficult to provide external power input in many cases.

In these cases, external power is used to facilitate the desired flow modification and the concomitant improvement in the rate of heat transfer

II. LITERATURE SURVEY

A. Joardar, A.M. Jacobi[1] The effectiveness of delta-wing type vortex generators is experimentally evaluated by full-scale wind-tunnel testing ofa compact heat exchanger typical to those used in automotive systems.

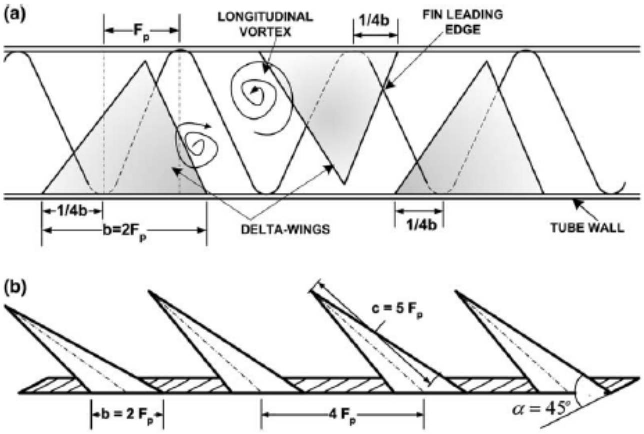


Fig. No.1Vortex generator implementation: (a) wing placement as shown (with a 1/4-span offset) ensures provides one vortex passes into each inter-fin space; (b) wings are manufactured by wire EDM as strips with 10–20 wings each[1]

The mechanisms important to vortex enhancement methods are discussed, and a basis for selecting a delta-wing design as a vortex generator is established. The heat transfer and pressure drop performance are assessed at full scale under both dry- and wet-surface conditions for a louvered- fin baseline and for a vortex-enhanced louvered-fin heat exchanger.

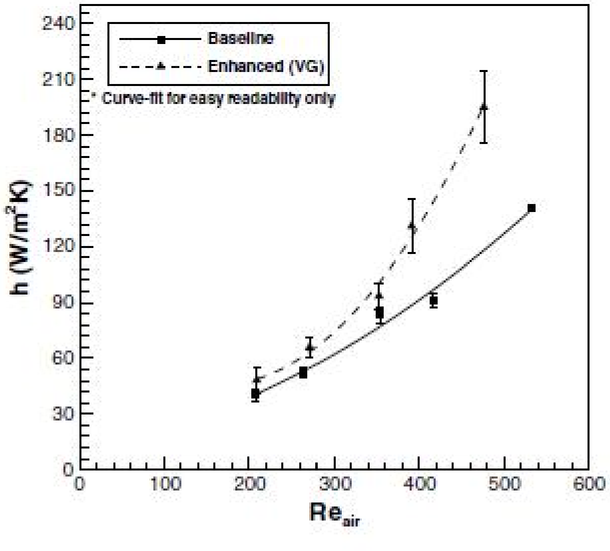


Fig.No.2 Heat transfer coefficient versus Reynolds number[1]

An average heat transfer increase over the baseline case of 21% for dry conditions and 23.4% for wet conditions was achieved with a pressure drop penalty smaller than 7%. Vortex generation is proven to provide an improved thermal-hydraulic performance in compact heat exchangers.

Mohd S Aris, Ieuan Owen, Chris Sutcliffe[2]This paper is concerned with the convective heat transfer enhancement of heated surfaces through the use of delta wing and wavy channels as longitudinal vortex generators. A preliminary proof-of-concept investigation has been carried out into the use of active vortex generators manufactured from Shape Memory Alloys (SMAs) which are activated at specified temperatures.

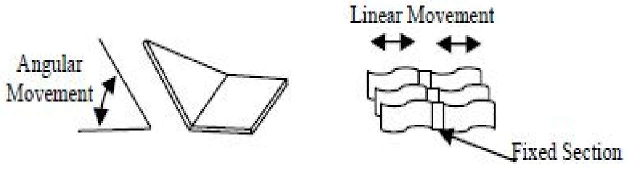


Fig. No.3 Delta Wing and Wavy Elements[2]

The delta wing vortex generators change their shape to intrude further into the flow at high temperatures to enhance heat transfer, while maintaining a low profile at low temperatures to minimise flow pressure losses. Similarly, the wavy channels enhance heat transfer by forming a close to sinusoidal wavy shape when activated at high temperatures and turn into straight channel passages when it is deactivated at lower temperatures.

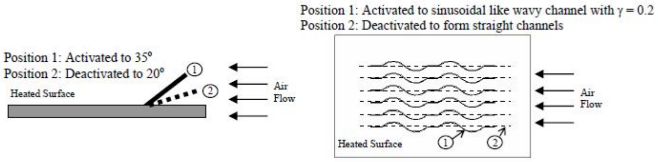


Fig. No.4 A Vortex Generator and Wavy Elements at their Activated and Deactivated Positions [2]

As with the delta wings, a lower flow pressure loss is achieved when the channels are deactivated. One set of vortex generators was made from pre-alloyed powders of SMA material in a rapid prototyping process known as Selective Laser Melting (SLM). Another set of devices were made from commercially available flat annealed thin SMA sheets for comparison. Promising results were obtained for both the vortex generator designs when their temperatures were varied from 20^o to 85^{o}C. The delta wing vortex generator responded by increasing its angle of attack from 20^o to 35^o while the wavy channel elements acquired a waviness aspect ratio of 0.2. As the designs were two-way trained, they regain their initial position and shape at a lower temperature. The surface temperature of the heated plate on which the active devices were positioned were seen to reduce locally from 120^{o}C to 40^{o}C, indicating heat transfer enhancement due to the generated longitudinal vortices.

Jalal M. Jalil, Hassan K. Abdullah and Ahmed H. Yousif[3] Experimental investigation of the flow and heat transferaround a heated cylinder in cross flow with and without using winglets has been carried out. Distribution of the static pressure coefficients and Nusselt number and knowledge of the flow processes around the cylinder without winglets enable as to form an idea of the mechanism and pattern of the flow around the cylinder with winglets.

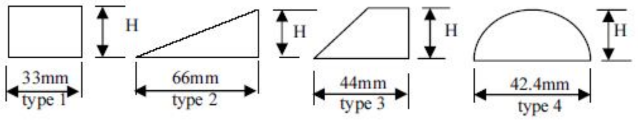


Fig. No.5Schematic view of winglets[3]

The flow was in fully-developed turbulent flow with Reynolds number range 0.72*104≤Re≤1.44*104. Four different shapes of winglets were used with different angles of attack (20, 26, 32) at different locations ((Xm/D=0, 0.17, 0.3, 0.5), (Ym/D=0.57, 0.65, 0.72, 0.8)). The results show that there is an effect of winglet shapes on heat transfer and pressure drop, and a better shape is a (trapezoidal (type 3)). For enhanced heat transfer from cylinder, heat transfer increases with increasing Reynolds number and angle of attack. Also the results show that the optimum position of winglet for enhanced heat transfer is (Xm/D=0.17 and Ym/D=0.65).

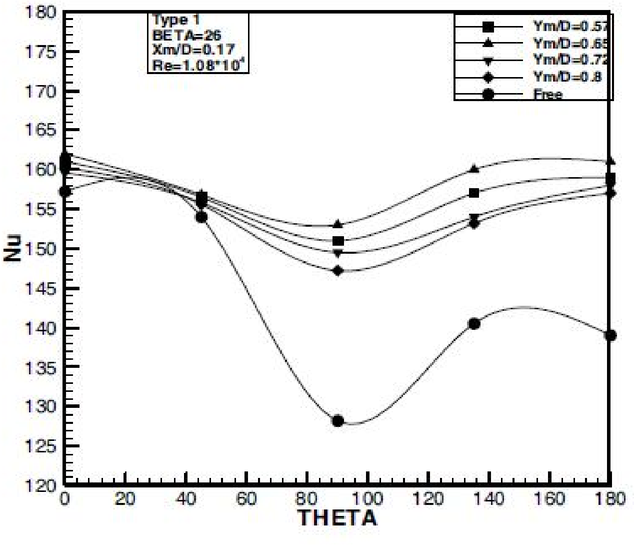


Fig. No.6 Variation of Nu with angle of attack [3]

The research shows that heat transfer is enhanced as high as (14%) when winglets are used when compared with the case of a cylinder without winglets. There is also a slight increase in pressure drop

Y. Chen, M. Fiebig, N.K. Mitra[4] Punched longitudinal vortex generators in form of winglets in staggered arrangements were aemployed to enhanceheat transfers in high performance finned oval tube heat exchanger elements. Three-dimensional hydrodynamicallyand thermally developing laminar flow (Re= 300) and conjugate heat transfer in finned oval tubes were calculatedby solving the Navier-Stokes and energy equations with a finite-volume method in curvilinear grids. Velocity field,pressure distribution, vortex formation, temperature fields, local heat transfer distributions and global results forfinned oval tubes with two to four staggered winglets (b=308, L=2, h=H) were presented and compared. Wingletsin staggered arrangement bring larger heat transfer enhancement than in in-line arrangement since the longitudinalvortices from the former arrangement influence a larger area and intensify the fluid motion normal to the fowdirection. For Re = 300 and Fi = 500, the ratios of heat transfer enhancement to flow loss penalty (j/j0)/(f/f0) were1.151 and 1.097 for a finned oval tube with two and four staggered winglets, respectively.

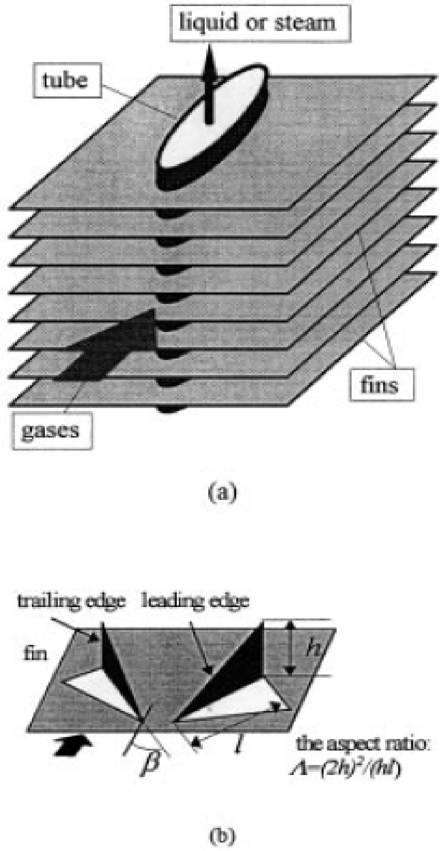


Fig. No.7(a) A finned oval tube heat exchanger element; (b)schematic of a delta winglet pair (DWP).[4]

BalvinderBudania and HarshdeepShergill[5] In this research work heat transfer and fluid flow characteristics in a channel in the presence of a triangular prism has been numerically investigated in the laminar flow regime.

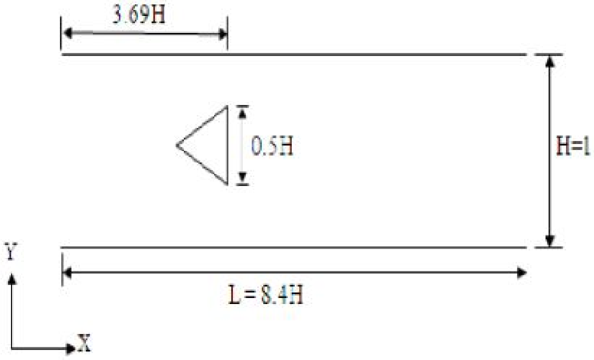


Fig. No.8 A parallel plate channel having triangular prisms with blockage ratio 0.5[5]

The computations are performedfor a Reynolds number of 50 and blockage ratio (b) of 0.25, where blockage ratio is the ratio of prism base to thechannel height. The Navier Stokes equations along with the energy equation have been solved by using SIMPLETechnique. The unstructured triangular mesh is used for the computational domain.

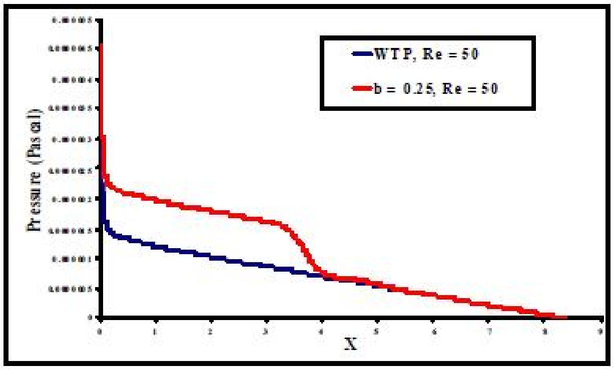


Fig. No.9 Pressure variation along the channel length with a blockage ratio of 0.25 and without prism at Re = 50.[5]

The results show that in thepresence of triangular prism the average Nusselt number is 7.37 % more as compared to plane channel. Theenhancement is due to the formation of vortices which travels long way in the downstream direction. It is furtherobserved that the heat transfer increases with the increase in blockage ratio (b) and also by increasing theReynolds number (Re). The effect of inserting dual prisms in different arrangement is also investigated. Heattransfer enhancement for triangular dual prisms is more as compared to the single triangular prism for sameblockage ratio. However the heat transfer enhancement is associated with greater pressure drop.

III. PROBLEM STATEMENT

From literature survey we can say that Less work on Curved Semicircle delta wing vortex generator so it is need to investigate detail geometrical parameters for Curved Semicircle delta wing vortex generator

IV. OBJECTIVE OF THE WORK

1. Investigation of Heat transfer enhancement in Curved Semicircle delta wing vortex generator
2. Pressure drop estimation in Curved Semicircle delta wing vortex generator
3. Thermal Performance enhancement analysis in Curved Semicircle delta wing vortex generator
4. Will Propose best geometry which gives maximum Thermal Performance

V. EXPERIMENTAL SETUP

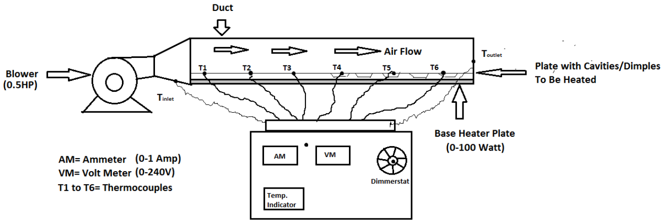


Fig No. 10 Experimental setup

The schematic diagram of the experimental facility is shown in fig. 3.1. An actual photograph of the test set-up is shown in the photo gallery in fig. 1

Tests were carried out in a rectangular Acrylic duct and the Acrylic duct is connected to the blower by means of a cylindrical pipe section via aluminium tape section.

The duct is open from the bottom of the duct to insert the plates and heater assembly.

The test plate is directly kept on the Nichrome plate heater.

Insulation is provided beneath the plate heater by applying the thermal paint and placing asbestos and plywood sheet.

The plate, heater and the insulating material are clamped together to form a single assembly.

This assembly is inserted in the duct from bottom open part is open.

A flow control valve is provided on the blower inlet so has to control the discharge of the blower. Flow rate was measured using a digital anemometer.

Connected to a wattmeter which is further connected to the dimmerstat. The wattage of the plate heater is the heater is varied with the help of the dimmerstat.

The blower, wattmeter, digital temperature indicator and dimmerstat are connected individually to the main supply of 230 volt.

K–type thermocouples are used to measure the temperatures inside the duct. Eight thermocouples are used to measure the surface temperature of the test plate at different locations. One thermocouple is used to measure the inlet temperature of air inside the duct and another thermocouple is used to measure outlet temperature. an universal data logger is used to displayed the measured temperature by the thermocouples.

Differential pressure sensor is connected by means of probes to the duct. One probe is connected just before the test section and one just after the test section.

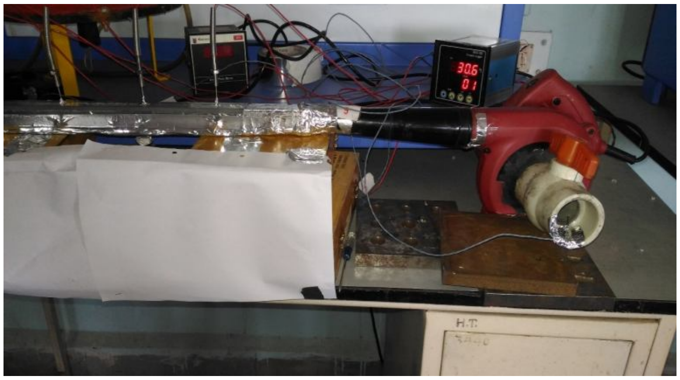


Fig. No. 11 Actual experimental setup

Theoretical analysis

Heat absorbed by air

$Q = \dot{m}\, Cp\, \Delta T$

$\dot{m} = \rho A V$

ρ = Density of air

Q = Heat absorbed by air

A = Area of cross section of duct

$\dot{m}$ = Mass flow rate of air

v = Velocity of air

Cp = Sp. heat of air at constant press.

$\Delta T = T_{out} - T_{in}$

Heat Convected

Heat absorbed by air = Heat Convected

$$Q = h\, Ap\, \Delta T$$

heat transfer coefficient is = $h = \frac{Q}{Ap \times \Delta T}$

Ap = Surface area of plate

ΔT= mean temp. of plate – mean temp. of air

Nusselt number calculations:

$Nu = \frac{h\,D}{k}$

Where, $D = \frac{2WH}{W+H}$

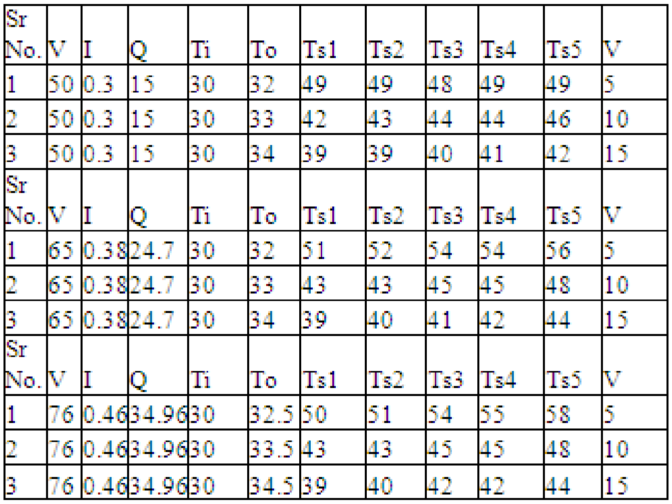
D = Hydraulic diameter of duct, H= Height of duct, k =;

Conductivity of air,

W= width of duct

VI. OBSERVATION TABLE

Offline Semi curved Vortex generator



Sr No.	V	I	Q	Ti	To	Ts1	Ts2	Ts3	Ts4	Ts5	V
1	50	0.3	15	30	32	49	49	48	49	49	5
2	50	0.3	15	30	33	42	43	44	44	46	10
3	50	0.3	15	30	34	39	39	40	41	42	15
Sr No.	V	I	Q	Ti	To	Ts1	Ts2	Ts3	Ts4	Ts5	V
1	65	0.38	24.7	30	32	51	52	54	54	56	5
2	65	0.38	24.7	30	33	43	43	45	45	48	10
3	65	0.38	24.7	30	34	39	40	41	42	44	15
Sr No.	V	I	Q	Ti	To	Ts1	Ts2	Ts3	Ts4	Ts5	V
1	76	0.46	34.96	30	32.5	50	51	54	55	58	5
2	76	0.46	34.96	30	33.5	43	43	45	45	48	10
3	76	0.46	34.96	30	34.5	39	40	42	42	44	15

VII. RESULTS AND FINDINGS

Figure 12,13 and 14 shows that variation of Heat transfer coefficient with Reynolds Number on Smooth plate, inline and offset Semi curved Vortex Generator with different power input. Reynolds number varies from 5000,10000,15000. Graphs shows maximum heat transfer coefficient at 35 W power input.

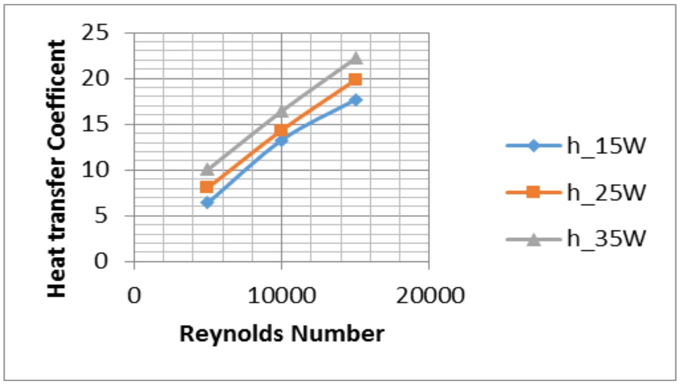


Fig. No. 12 Variation of Heat transfer coefficient with Reynolds Number on Smooth plate

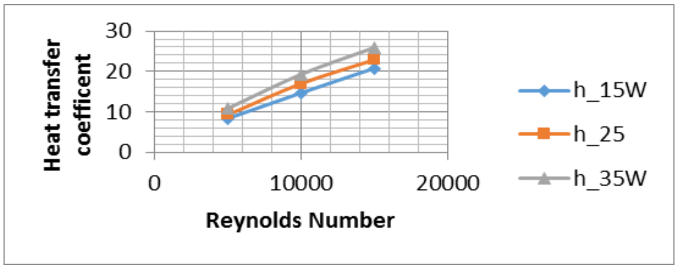


Fig. No.13 Variation of Heat transfer coefficient with Reynolds Number on Inline Semi curved Vortex Generator

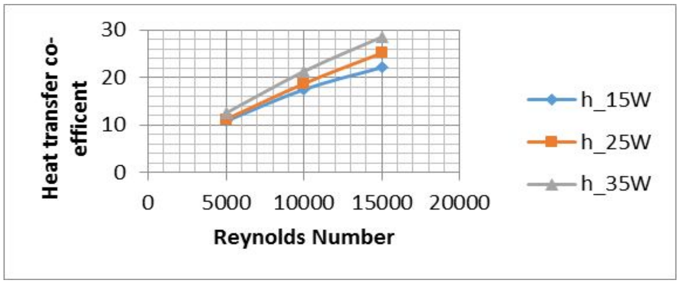


Fig.14 Variation of Heat transfer coefficient with Reynolds Number on offset Semi curved Vortex Generator

Figure 15,16 and 17 shows that variation of Heat transfer coefficient with Reynolds Number on Smooth plate, inline and offset Semi curved Vortex Generator with different power input. Reynolds number varies from 5000,10000,15000. Graphs shows maximum heat transfer coefficient at 35 W power input with offset Semi curved Vortex Generator.

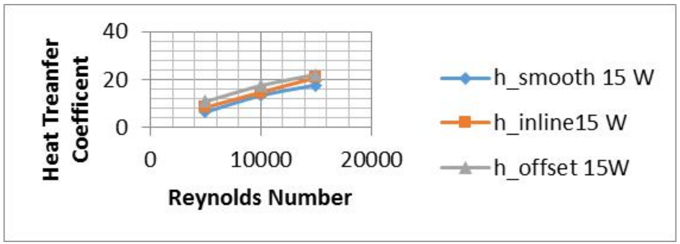


Fig.15 Variation of Heat transfer coefficient with Reynolds Number at 15 Watt on Smooth, inline and offset Semi curved Vortex Generator

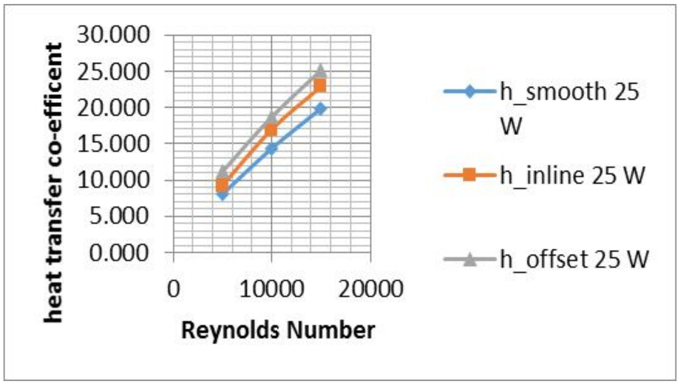


Fig.16 Variation of Heat transfer coefficient with Reynolds Number at 25 Watt on Smooth, inline and offset Semi curved Vortex Generator

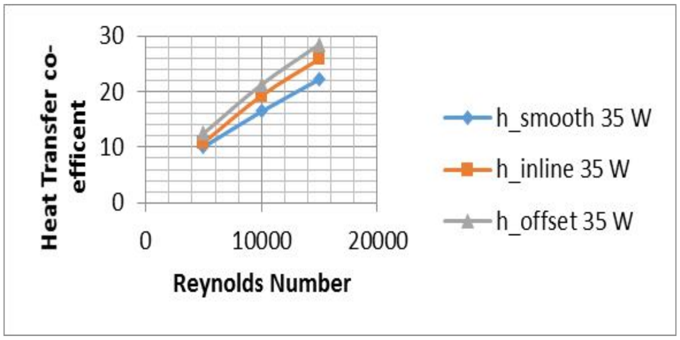


Fig.17 Variation of Heat transfer coefficient with Reynolds Number at 35 Watt on Smooth, inline and offset Semi curved Vortex Generator

Figure 18 shows that combined variation of Heat transfer coefficient with Reynolds Number on Smooth plate, inline and offset Semi curved Vortex Generator with different power input 15,25,35. Reynolds number varies from 5000,10000,15000. Graphs shows maximum heat transfer coefficient at 35 W power input with offset Semi curved Vortex Generator. Figure 4.8 shows variation of pressure drop on Smooth plate, inline and offset Semi curved Vortex Generator. This graph shows there is maximum pressure drop in offset Semi curved Vortex Generator.

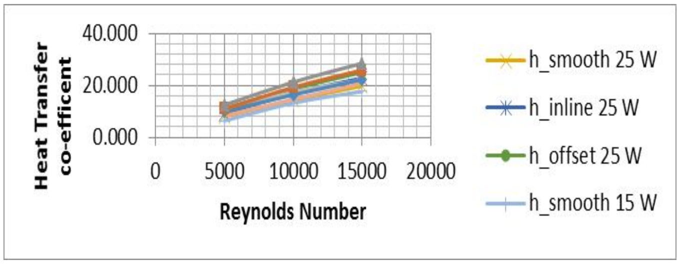


Fig.18 Variation of Heat transfer coefficient with Reynolds Number at 15,25 and 35 Watt on Smooth, inline and offset Semi curved Vortex Generator

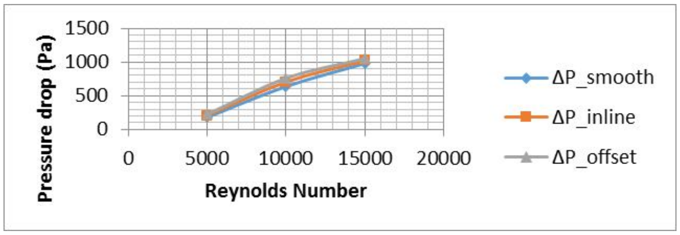


Fig.19 Variation of Pressure drop with Reynolds Number on Smooth, inline and offset Semi curved Vortex Generator

Figure 20 shows that variation of Performance Enhancement factor (PEF) with Reynolds Number on inline and offset Semi curved when compared with smooth plate. Reynolds number varies from 5000,10000,15000. Graphs shows maximum Performance Enhancement factor for offset Semi curved Vortex Generator than inline Semi curved Vortex Generator.

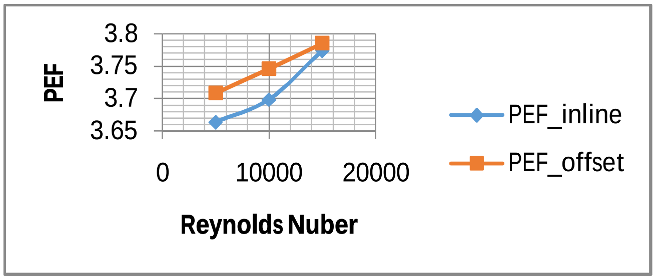


Fig.20 Performance Enhancement Factor of inline and offset Semi curved Vortex Generator

VI. CONCLUSION

Experimental investigation of on Smooth, inline and offset Semi curved Vortex Generator on a flat plate is carried out and heat transfer characteristics were studied for each case with diff variable parameters with respect to input power and velocity.

The important findings of the experimental investigations are as follows-

With different of arrangements such as flat, inline and offset and with variable parameter such as velocity, v = 5 m/sec, v = 10m/sec, v = 15m/sec for this conditions cases are studied and it has been found that the offset arrangement in divergent plate gives optimum solution as compared to other arrangementsIt is observed from the experimental results that the Performance Enhancement factor for offset Semi curved Vortex Generator than inline Semi curved Vortex Generato importance of the work or suggest applications and extensions.

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