Efficiency Enhancement of Fin Tube Heat Exchanger Using New Winglet Vortex Generator

R Srinivas[1], Kotamarthi Vijay[2]
[1, 2] Aditya college of engineering and technology ,Surampalem,
Andhra Pradesh, India

Abstract*- High performance requirement for thermal systems in engineering applications have led researchers to search for enhancement techniques that will increase heat transfer rates in systems. Longitudinal vortex generation is a common technique for enhancing heat transfer performance. It can be achieved by employing small flow manipulators, known as vortex generator (VGs), which are placed on the heat transfer surface. The vortex generators (VGs) can generate longitudinal and horseshoe vortices. These vortices strongly disturb the flow structure and have significant influence on the velocity and temperature fields, which in turn cause heat transfer enhancement. The main aim of this study is The effects of the different configurations of the vortex generator types is used in the CFD simulation to obtain the accurate results the geometrical optimization is used in the project using the shapes like Gothic, Rectangular, Triangular, Parabolic, Ogive to determine which shape gives the optimum heat transfer in all the arrangement's standard boundary conditions is adopted to conclude the shape of the heat exchanger vortex generator.*

Keywords- Vortex Generator , CFD, Gothic, Rectangular, Triangular, Parabolic, Ogive.

I. INTRODUCTION

A heat exchanger is a complex device that provides the transfer of heat energy between two or more liquid, they are in a different temperature, the heat, the link between each other. Heat exchangers, use either separately or as part of a large cooling systems, in a wide variety of commercial, industrial and domestic applications, for example, electricity, Refrigeration, Ventilation and air conditioning systems, manufacturing, aviation and aerospace industry, electronic chip heat dissipation, as well as in environmental engineering. The improved performance of the heat exchanger has attracted many researchers for a long time, because they are very technical, economic, and not least, the ecological importance. Improved performance becomes essential, especially in the heat exchanger of gas, because the thermal resistance of the gases can be 10 to 50 times the liquid (tiggel beck et al., 1992), which requires a significant amount of heat per unit volume of gas. The traditional approach to reduce air-side thermal resistance is achieved by increasing the surface area of the Heat Exchanger, or to reduce the thermal boundary layer thickness on the surface of the heat exchanger. The increased surface area is effective, but it will result in an increase in the cost of materials and increase public awareness of the heat exchanger. One way to reduce the boundary layer thickness is determined by the next generation of passive vortices. In this type of technology in the field of circulation change an obstacle to produce a spiral toward the direction. The resulting change in flow, because of the changes in the local obstacles to a thermal boundary layer. The end result of this process is an average increase heat transfer to the affected area. The current work is to calculate the thermal enhancement can be achieved at all levels in a plate heat exchanger (and the heat sink in the triangle between the board with built in the vortex generator is mounted on the heat sink in the form of small rectangular wing.

1.2 Classification of Heat Exchangers

Heat exchangers may be classified according to Shah (2002) and Hewitt et al. (1994) as

(a) Recuperators or regenerators
(b) Transfer Process (Direct contact or indirect contact)
(c) Type of construction (tubes, plates and extended surfaces)
(d) Heat transfer mechanism (single phase and two phase)
(e) Flow arrangement (Parallel flow, counter flow or cross flow)

Many applications require the space to be occupied by the exchanger to be kept as low as possible. The Compact heat exchangers serve this purpose along with the required amount of energy exchange and low fluid inventory.

II. LITERATURE

This chapter reviews previously reported work by other researchers in the field of effect of vortex generators on heat transfer enhancement.

Jacobi and Shah [1] provides an excellent review of the surface of the heat transfer enhancement through the use of longitudinal vortices. They looked at the active and passive implementation of Vortex generator to heat transfer. The following is the focus of the review articles that are particularly relevant to the current research.

The use of multi-dimensional data sets and a small delta wing Vortex generators are looked at, Edwards and alker [2]. A uniform heat flux is applied to a flat surface, as well as the impact of the evaluation of heat through the enhancement of local surface temperature measurements with fluorescent phosphor technology. The experiment for the builder's size and spacing at constant Reynolds number 61000 (depending on the height). The data is collected from the two co and counter-rotating vortex pair. The results show that the multi-dimensional data set provides the best local heat transfer enhancement, 76 per cent of the successful case. The highest increase with the delta 42 per cent of small wings in a reverse rotation of the whirlpool.

Russell and others. [3] the use of the vortex generator to improve the performance of the finned tube heat exchanger. The lab is the use of transient fuse technology to record the local heat enhanced triangle and rectangle of the winglet Vortex generator. When the pressure drop with enhanced functionality that is also recorded. The author found that the small rectangular wing placed in two staggered lines provide the best overall performance. A comprehensive fins flat tube heat exchanger was tested in a small rectangular wing 20° angle of attack. The experimental data, compared to a normal FIN associations from the literature (rather than the experimental data from one exactly the same heat exchanger, no heat transfer enhancement). In the Renault for 1000, colburn j factor is increased by about 50%, while the coefficient of friction f increased by about 20%.

For Reynolds numbers between 1500 and 2200, the ratio of j/f was reported to exceed 0.5. The authors concluded that the vortex generators offered a powerful type of heat transfer enhancement.

Turk, junkhan [4] evaluation of the impact of different aspect ratio and angle of the winglet vortex generator is a local heat transfer on a flat plate. In this lab, a known, constant heat flux applied to the flat plate downstream of the vortex generator. The local surface water and air temperature measured by thermocouple, and from these measurements, the local heat transfer coefficient is inferred. The author believes that the flow is zero or positive pressure gradient, and reported that, in general, the enhancements added a favorable pressure gradient. The local cross-wise average heat transfer enhancement to 250% coverage.

Fiebig et al.[5] studied the heat transfer to Strengthen triangular wing and small wings in the flat channel, the Reynolds number based on the plate spacing in the range 1360-2270. Qualitative data, use the Laser Sheet Flow Visualization technology, and the heat transfer behavior is measured using the unstable, lcd thermal imaging. In this technique, originally a cool fin stack is suddenly inserted into a hot air flow wind tunnel. The transient heating of the heat sink surface. By tracking the movement of a single isotherm on the plate surface. In the convection heat exchanger and is equivalent to the internal energy of the fins, and local heat transfer coefficient is calculated. The authors reported that the triangular wing geometry is one of the most promising one, and local enhancements of up to 200%. Overall colburn j, has increased by 20 to 60% of the Renault for 1360 Delta-wing angle of attack, from 10° to 50°.

Biswas says et al.[6], one of the first digital projects arising out of the vortex heat exchanger enhancement, investigation, and mixed-flow', a rectangular channel. The calculation of the Reynolds number is 500 and 1815, grashof number is 0, 5, and 5. They 5.0E 2.5E evaluation, a single triangular wings, their aspect ratio and the angle of attack, 20° and 26°. The wing is attached to the back wall of the channel, its rear edge. It should be noted that this study is not included in the hole on the underside of the wing which would result from their being beaten for a fin.

Biswas says, chattopadhyay [7] determine the order in which the figures as an extension of previous work, the structure of the flow and heat transfer characteristics of a rectangular channel, a built-in triangular wings extend from the bottom of the wall. They calculate the digital solution for the complete navier-stokes and energy equations. They looked at the effect of a punch holes in the lower wing turbine generator, the heat transfer and skin friction characteristics have been identified. They investigated the impact of Vortex generator angle of attack and the number of heat transfer and skin friction. They show that the average nu number increases to 34% at an angle of 26°.

Gentery and jacobi[8] of 50% to 60% average heat and mass flow over a flat, the Reynolds number using the delta-wing turbine generator of new data, they use a simple method for evaluating the parameters from the current visual data. They find the best delta-wing geometry of the Reynolds number 600,800, and 1000 is based on the wing chord length. The results are used to develop a better understanding of the interactions between vortices and boundary layer. They

reported that, when a high-flow turbine is placed near the edge of the boundary layer, it effectively thins boundary layer.
Brockermeier et al.[9] to perform a similar figures for research in order to assess their impact on the generation of the whirlpool of forced convection parallel between the plates. The triangular wing and small wings, and the hole under the wing is included. A triangular wing aspect ratio, one is considered to be used to attack angle different from 10° to 50°, the Reynolds number was varied, from 1000 to 4000. To calculate the predicted maximum cross flow velocity in the same order as the vortex mean axial speed. The cross-section of the delta wing vortex is said to be elliptical, because the rotation of the whirlpool of the wall distort its cross section. Wing with small increments over 30° angle of attack and the number is 4000, this is an average increase of 84% of the nusselt number is predicted.

Fiebig et al.[10] extension of brockermeier et al.[9], the report said that there is a shaft speed to the whirlpool whirlpool's core, which allows you to maintain a stable triangular wing angle of attack exceeds 50°.

Fiebig et al [11] extension of their previous work ([5]) through the evaluation of the impact of the vortex generated by the movement of the channel. The triangle and rectangular wings and winglets were evaluated using the unstable, lcd thermal imaging technology to the aspect ratio from 0.8 to 2.0, the attack from a different angle of 10° to 60°, and Renault are different, from 1000 to 2000. In the lab, the pressure drops too low, the author chose to measure changes, drag-and-drop-in a specimen hanging in the wind tunnel. They refer to the numerical results, the error is reported and their implicit will drag and total pressure drop to below 6 percent.
Tiggelbeck et al.[12] surveys using the same process visualization and unstable lcd thermal imaging technology. The study has been further expanded to include two alignment line delta winglets. They reported that the qualitative flow structure, some developing countries vortices each turbine generator, their data stream and discover the wisdom of development is nearly independent of the oncoming flow Vortex generators, (or vertical). In other words, the second row of the vortex generator is much like the first row. Local heat transfer enhancement is one of the most behind the second row of generators, but the effect of the enhanced rate faster flow, under the wise leadership of the generators in the second row is the first row. For a 5600 Renault, local heat transfer enhancement of hundreds of percentage points, as well as the average Heat conduction is increased by 77 per cent of the two lines of the alignment of the vortex generator. No pressure drop data is recorded.

Tiggelbeck et al.[13] extension of this multi-line vortex generator work, including the wrong vortex generator and the pressure drop in the lab. Once again, the qualitative flow structure, the number of vortices each generator and sensible development that is nearly independent of the upstream flow conditions. The staggered arrangement to give a high degree of low thermal conductivity and enhanced features than the built-in arrangements, however, cutting the pressure drop than embedded within the organization. Average heat, it was observed that 80 will increase by 10%, and an angle of 45°, the number is 6000.

III. METHODOLOGY

Computational Fluid Dynamics also generally called CFD is an important branch of fluid mechanics and it uses numerical methods and algorithms to analyze and solve fluid flow problems. It has become popular since the previous methods, experimental and theoretical are either very expensive, time consuming, or involve too much labor. In CFD, computers are used to solve the algorithms that define and analyze the fluid flow. Due to the increase in the computational capabilities over time and better numerical solving methods, most experimental and theoretical work has been done using CFD. CFD is not only cost effective but it helps one analyze and simulate complex geometries, heat transfer, and shock waves in a fluid flow. It also helps solve partial differential equations (PDE) of any order in a fluid flow. CFD mainly helps analyze the internal or external fluid flow. The use of CFD has become increasingly popular in branches of engineering such as Aerospace to study the interaction of the propellers or rotors with aircraft fuselage, Mechanical to obtain temperature distribution of a mixing manifold, Bio-medical engineering to study the respiratory and circulatory systems. There are a few simple generic steps that must be followed for CFD analysis.

3.2 Governing Equations

Navier-Stokes equation plays a very important role for simulation of CFD problems. This comes from applying Newton’s second law to fluid motion. Partial differential equations define mass, momentum, and energy flow conservation.

In this study, the flow in the rectangular channel is considered laminar, incompressible, and steady state. The Navier-Stokes equation is shown in the simplest form. The following assumptions were made,

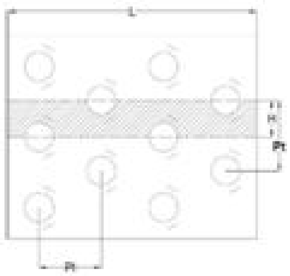
- It is a steady flow. Thus, this study does not depend on the time.

- The fluid has constant density and viscosity which means it is incompressible ρ = constant. Thus, the thermal changes that occur in the fluid because of constant density are neglected in this study.
- The only velocity component at inlet is in the direction of the flow, u = V. Thus, v = w = 0.

3.3 Model description

3.3.1. Physical Model

The figure. 3.3 (a) shows an example of the representative of the geometry of a four-fin tube heat exchanger is considered for numerical analysis. The small rectangular wings are installed on the managed the highest flow configuration. Tubes are staggering. Fin slice thickness, spacing, and size of the tube-like fin tube heat exchanger, widely used in the condenser Industrial refrigeration systems. As a result of the symmetrical arrangement, the area occupied by the dashed line, you can select the calculation domain, which is to be considered as a channel of Height H = 15.875 mm and L = 111.76mm.



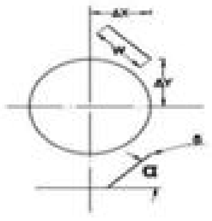


Fig.3.3 (a): computational domain

Fig. 3.3(b): Tube and VGs parameters

Tube Outside Diameter 12.7mm, so that the horizontal spacing pt is 1.25 inches, the longitudinal spacing pl is 1.1 inches, the FIN spacing fp is 2.12 mm, the leaf thickness of ∂ f is 0.15 mm. The aspect of the small rectangular wing has three different values (w = 5mm and 5.5mm and 6mm) thickness 0.15 ∂=false and is located in the (Delta X and Delta Y = 1.3). Also the angle of attack, the little wings are different, 300 and 450. The actual calculation domain is extended for 30 mm, exit, in order to ensure a free flow of recycling. The tube and rectangular turbine generator parameters, as shown in the figure. 3.3(b).

3.4 Boundary conditions

The air flow is assumed to be incompressible and volatile. RNG k-ε model is used as a turbulence model, taking into account the complex flows (wake-up or split) and anisotropic turbulence. All of the boundary conditions are given in the figure. 3.4(a).

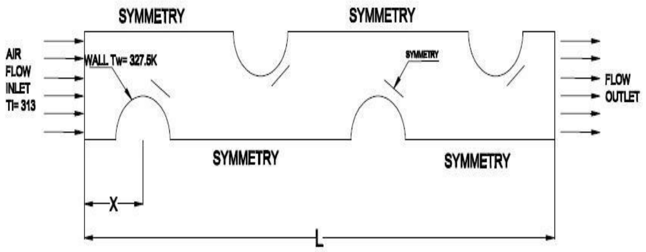


Fig. 3.4(a): The computational domain and boundary conditions.

The boundary conditions are as follows. One of the entry speed of boundary conditions (3.8 m/s) is established for the front-end of the field, and a pressure outlet boundary conditions are used for back-end symmetric boundary conditions are specified by the end of the side air flow paths. A constant temperature condition is set on the wall. The temperature of the solid surface is set so that the heat flux of the solid part of the balance and the adoption of the adjacent air. The top and bottom surface is set to heat. The inlet temperature is fixed at 313 K to all of the simulation. In the heat pipe wall temperature is set to 327.5 K to indicate the status of the Refrigerant condenser. The symmetric boundary conditions are used for the winglet VG.

Case 1: Rectangular VG

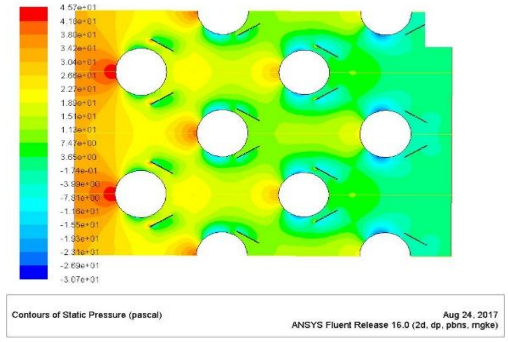


Fig 4.1 Contours of Static Pressure with Rectangular VG

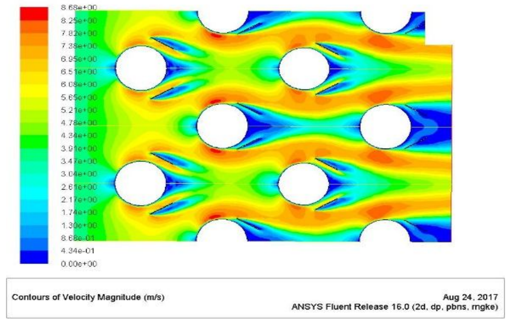


Fig 4.2 Contours of Velocity with Rectangular VG

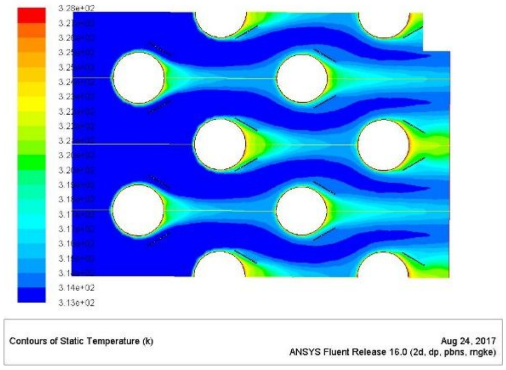
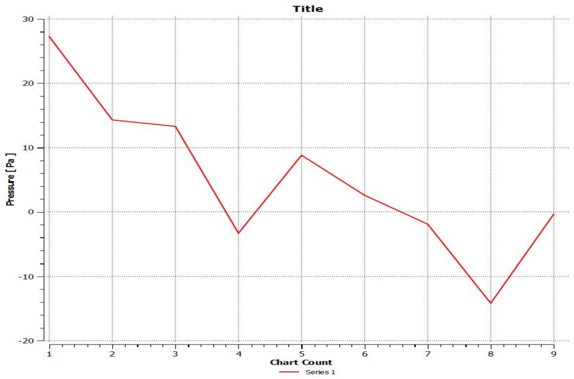
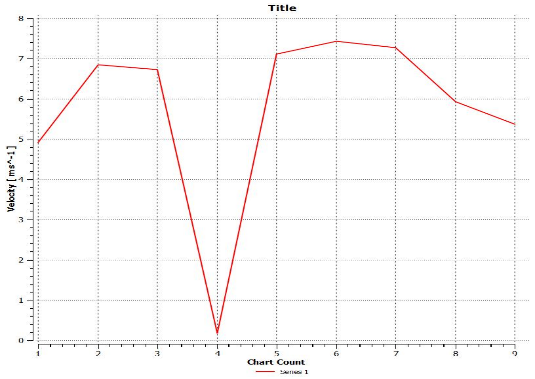


Fig 4.3 Contours of Static Temperature with Rectangular VG

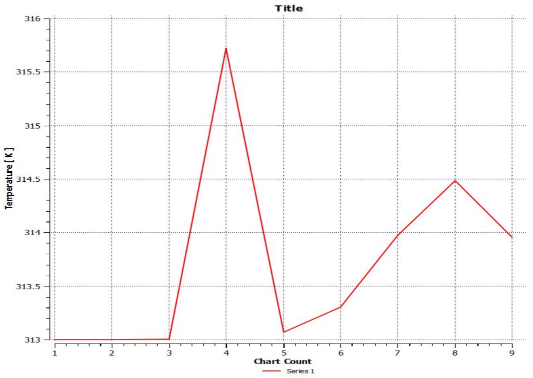
Plots



Plot 1 Pressure Vs Chart count through the heat exchanger length



Plot 2 Velocity Vs Chart count through the heat exchanger length with Rectangular VG



Plot 3 Temperature Vs Chart count through the heat exchanger length with Rectangular VG

Case 2: Triangular VG

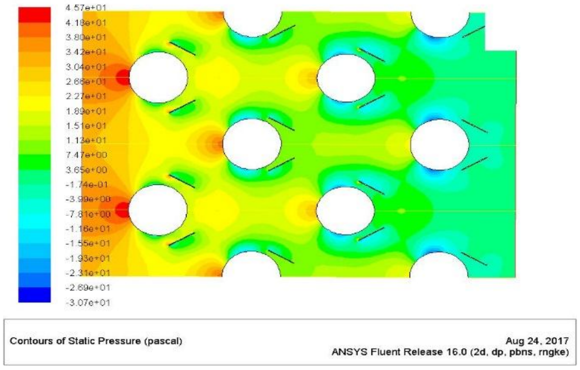


Fig 4.4 Contours of pressure TriangularVG

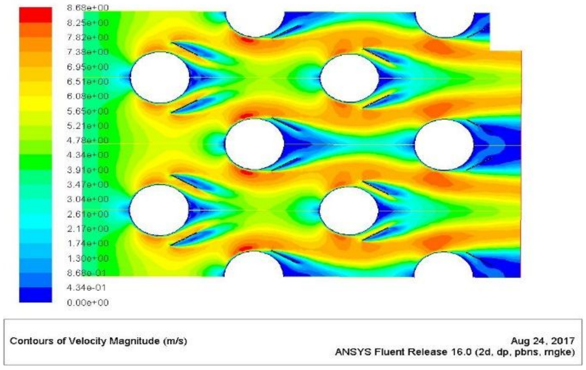


Fig 4.5 Contours of Velocity with Triangular VG

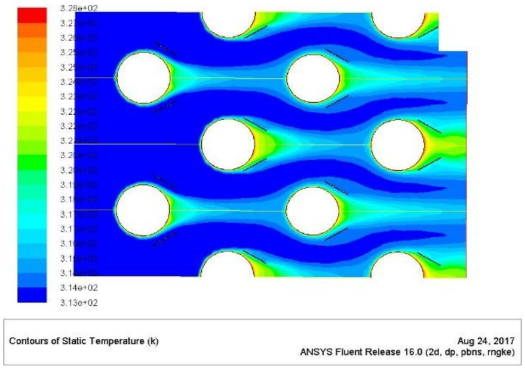
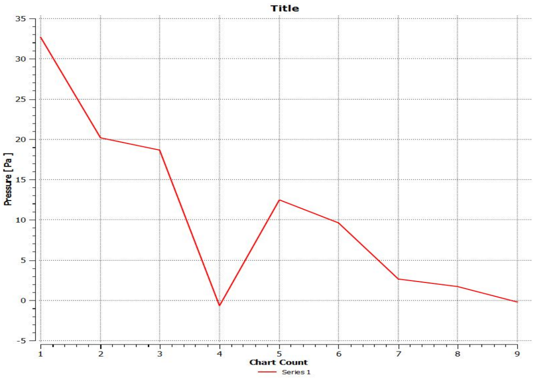
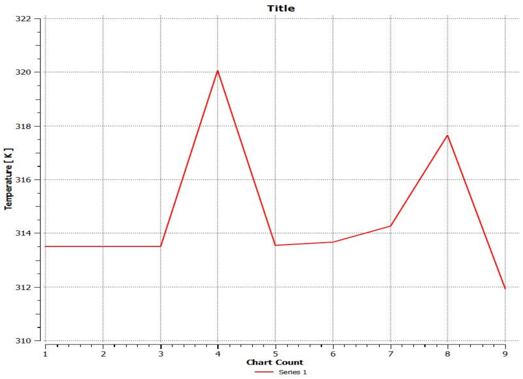


Fig 4.6 Contours of Temperature with Triangular VG

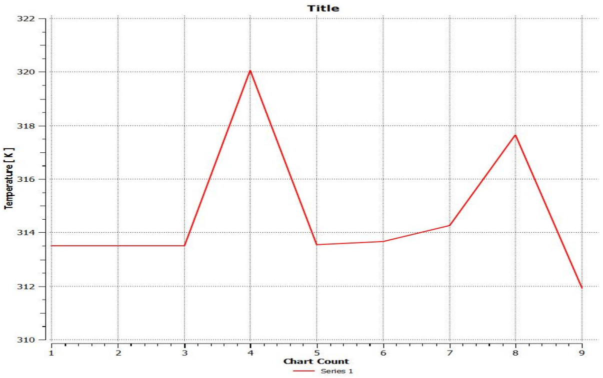


Plots

Plot 4 Pressure Vs Chart count through the heat exchanger length With Triangular VG



Plot 5 Velocity Vs Chart Count along the length of heat exchanger With Triangular VG



Plot 6 Temperature Vs Chart Count Through the heat exchanger length using triangular VG

Case 3: PARABOLIC VG

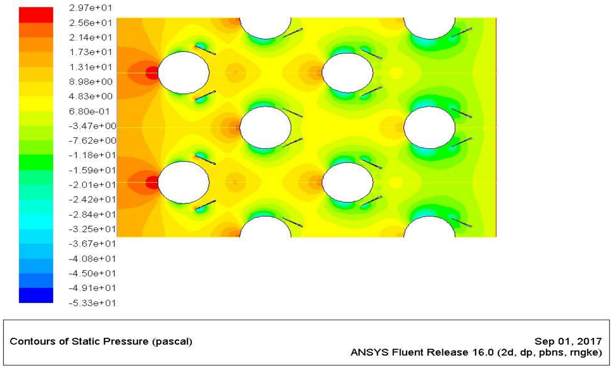


Fig 4.7 Contours of Pressure with Parabolic VG

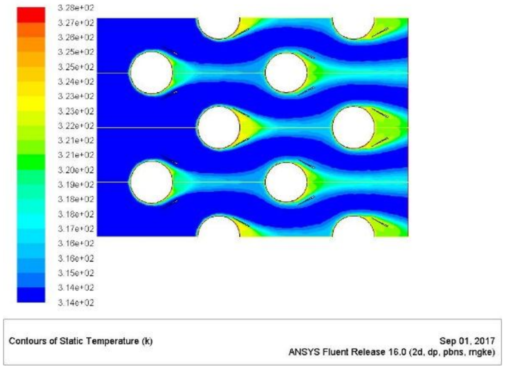


Fig 4.8 Contours of Static Temperature with Parabolic VG

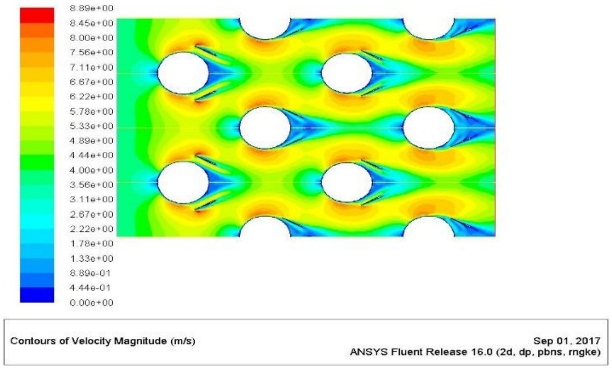
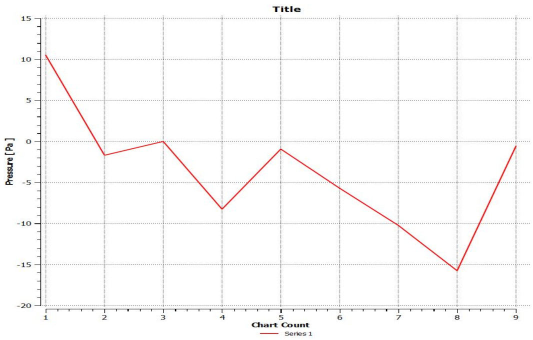
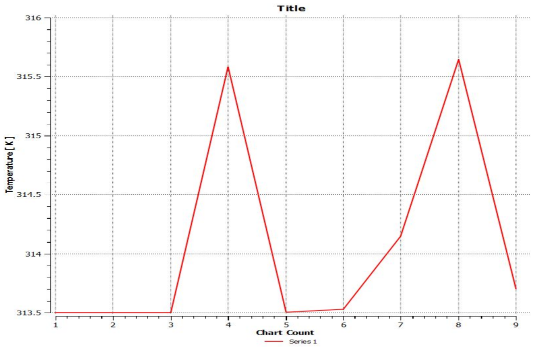


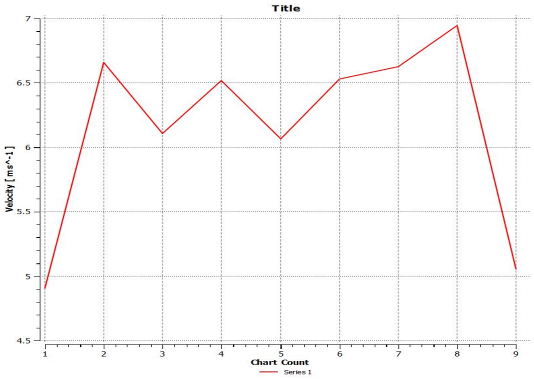
Fig4.9 Contours of velocity magnitude with parabolic VG



Plot 7 Pressure Vs Chart count through the heat exchanger length using parabolic VG



Plot 8 Temperature Vs Chart count through the heat exchanger length using parabolic VG



Plot 9 Velocity Vs Chart count through the heat exchanger length using parabolic VG.

Case 4: OGIVE VG

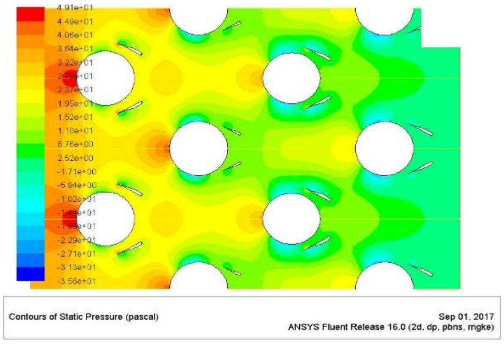


Fig 4.10 Contours of Pressure with Ogive VG

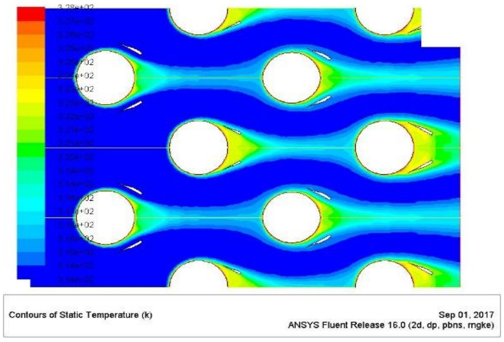


Fig 4.11 Contours of Static Temperature With ogive VG

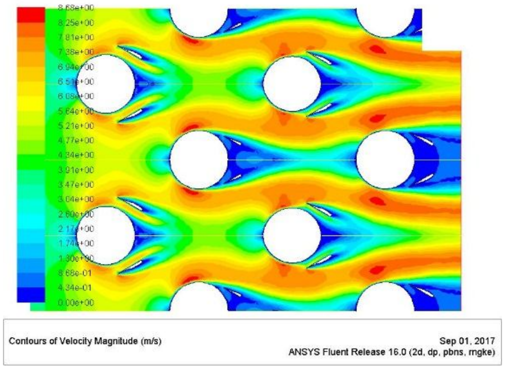
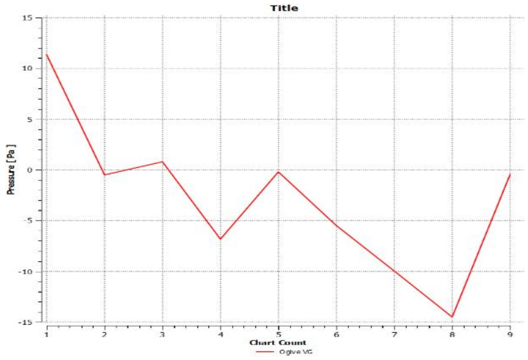
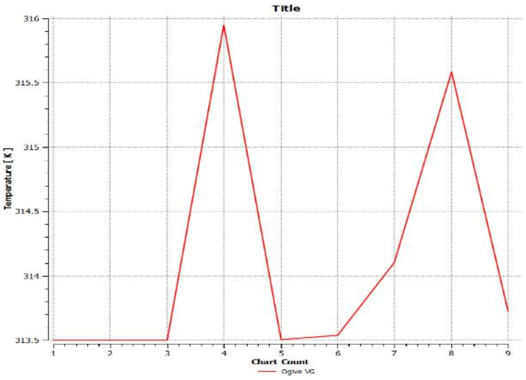


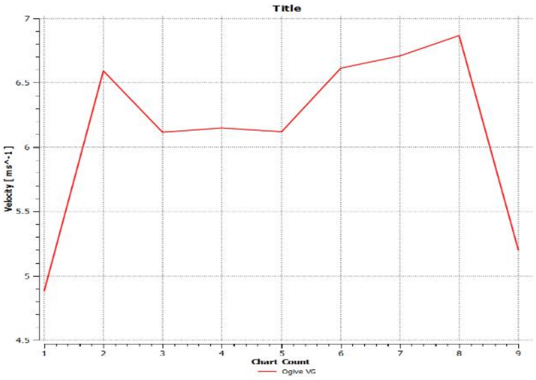
Fig 4.12 Contours of velocity magnitude with ogive VG



Plot 10 Pressure Vs Chart count through the heat exchanger length using ogive VG



Plot 11 Temperature Vs Chart count through the heat exchanger length using Ogive VG



Plot 12 Velocity Vs Chart count through the heat exchanger length using Ogive VG

Case 5: GOTHIC VG

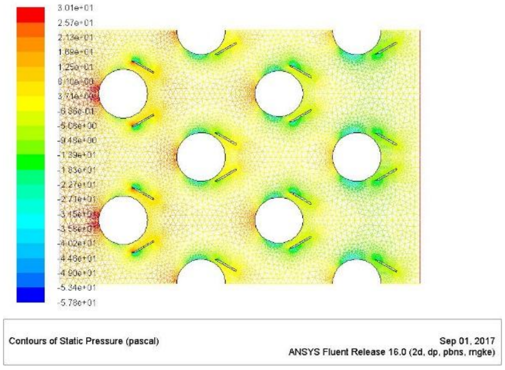


Fig 4.13 Contours of Pressure with Gothic VG

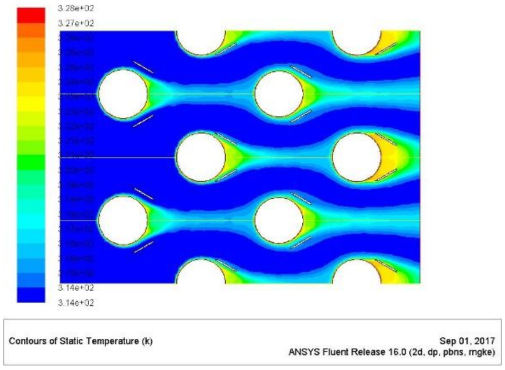


Fig 4.14 Contours of Temperature with Gothic VG

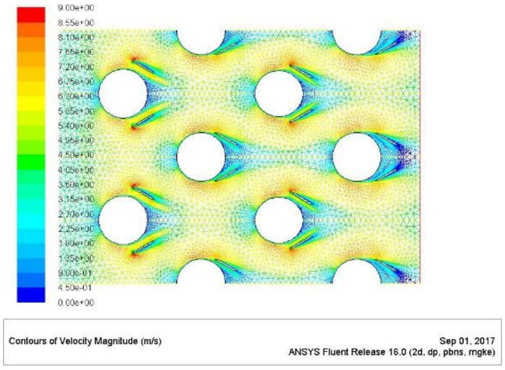
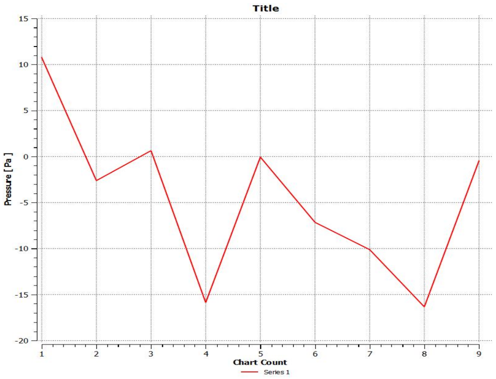
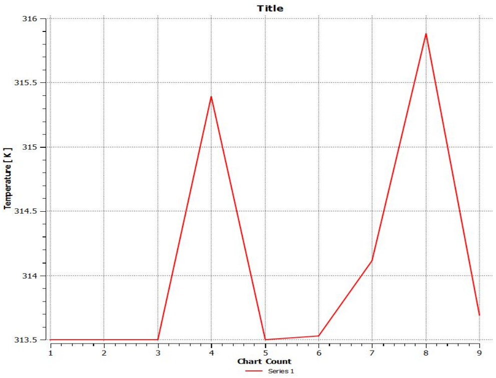


Fig 4.15 Contours of Velocity with Gothic VG

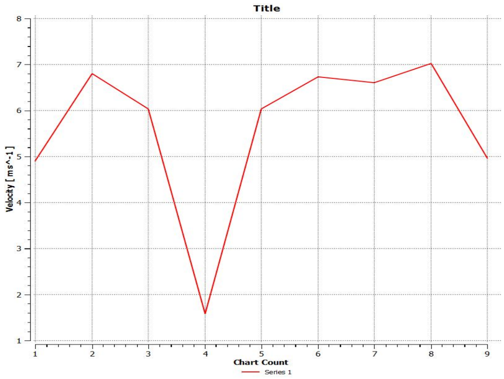
Plots



Plot 13 Pressure Vs Chart count through the heat exchanger length using Gothic VG



Plot 14 Temperature Vs Chart count through the heat exchanger length using Gothic VG

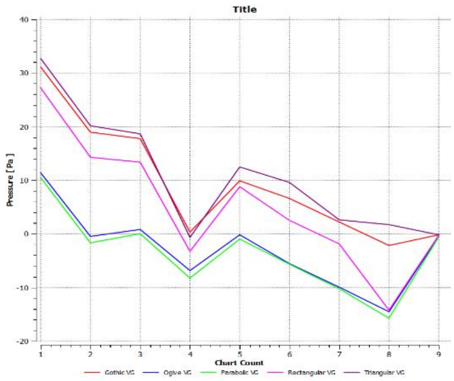


Plot 15 Velocity Vs Chart count through the heat exchanger length using Gothic VG

V. CONCLUSION

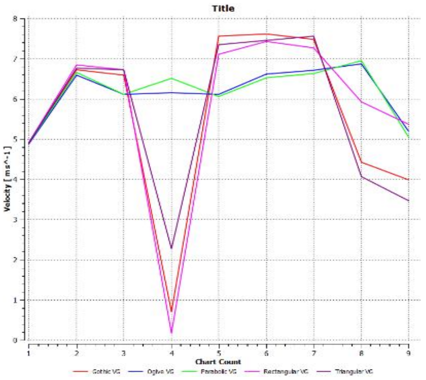
The results have been discussed in the Chapter 4 from the Results obtained through simulation following are the Comparison Graphs.

5.1 Pressure Comparisons of Different Vortex Generators.



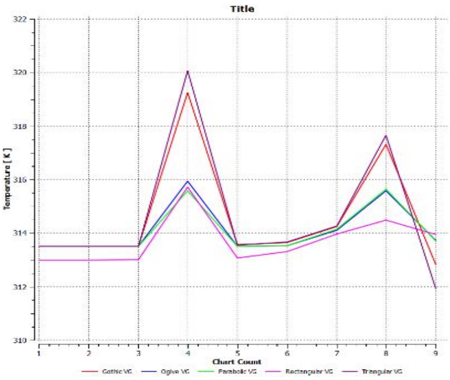
Plot 16 Pressure Comparison between Gothic, Ogive, parabolic, Rectangular and triangular

5.2 Velocity Comparisons of Different Vortex Generators.



Plot 17 Velocity Comparison between Gothic, Ogive, parabolic, Rectangular and triangular VG

5.3 Temperature Comparisons of Different Vortex Generators.



Plot 18 Temperature Comparison between Gothic, Ogive, parabolic, Rectangular, triangular VG

5.4 Conclusion

The fluid flow and heat transfer over a four rows tube bank in staggered arrangement with variation of Design of VGs, for Rectangular, Triangular, Parabolic, Ogive and Gothic, were studied numerically. The main results include:

1. The Results studied include the pressure velocity and temperature contours of the all five Vortex generators.
2. From the Plots we can say that triangular VG has the more heat transfer than considered with the other vortex generators.
3. Because of variant geometrical VG triangular generates more airflow in and around the heated wall when compared with other VGs such as Parabolic Ogive and Gothic.
4. Although parabolic and Ogive generated Recirculation in the VG area There is no change in the Heat transfer Rate.
5. From all these in the view we can conclude that for this particular application Triangular VG is suitable for more heat transfer

5.5 Scope of future work

The present study of “Efficiency enhancement of fin tube heat exchanger using new winglet vortex generator” can be extended to study further in future.

1. Experimentation may be done to rate the present findings.
2. Research is also needed to determine the behavior of the vortices with wet surface conditions
3. Most of the studies on fin heat transfer including present one have concentrated on the convective mode of heat transfer. Contribution of radiation heat transfer may be executed along with the convection to make the study more comprehensive.
4. Testing also needs to be performed on a full scale heat exchanger with internal vortex generators to determine the enhancement at other placements than the leading edge.
5. The orientation and position of vortex may be varied to find the possibility of further enhancement of heat transfer.

REFERENCES

[1] Biswas, G., Deb, P., and Biswas, P., 1994, “Generation of Longitudinal Stream wise Vortices – A Device for Improving Heat Exchanger Design,” ASME Journal of Heat Transfer, Vol. 116, pp. 588-597.

[2] Fiebig, M., Valencia, A., and Mitra, N. K., 1993, “Wing-Type Vortex Generators for Fin- and-Tube Heat Exchangers,” Experimental Thermal and Fluid Science, Vol. 7, pp. 287-295.

[3] Gentry, M. C., 1998, “Heat Transfer Enhancement Using Tip and Junction Vortices,” Ph.D. dissertation, University of Illinois, Urbana, IL.

[4] Jacobi, A. M., and Shah, R. K., 1995, “Heat Transfer Surface Enhancement through the Use of Longitudinal Vortices: A Review of Recent Progress,” Experimental Thermal and Fluid Science, Vol. 11, pp. 295-309.O’Brien, J. E., and Sohal, M. S., 2005, “Heat Transfer Enhancement for Finned-Tube Heat Exchangers with Winglets,” ASME Journal of Heat Transfer, Vol. 127, pp. 171-178.

[5] Sanders, P. A., and Thole, K. A., 2006, “Effects of Winglets to Augment Tube Wall Heat Transfer in Louvered Fin Heat Exchangers,” International Journal of Heat and Mass Transfer, Vol. 49, pp. 4058-4069.

[6] Shah, R. K., and Bhatti, M. S., 1987, “Laminar Convective Heat Transfer in Ducts,” Handbook of Single-Phase Convective Heat Transfer, Chap. 3, John Wiley & Sons, New York.

[7] Siegel, R., and Howell, J., 2002, Thermal Radiation Heat Transfer, 4th ed., Taylor & Francis, New York.

[8] Tsilingiris, P. T., 2003, “Comparative Evaluation of the Infrared Transmission of Polymer Films,” Energy Conversation and Management, Vol. 44, pp. 2839-2856.

[9] Yang, W.-J., 2001, Handbook of Flow Visualization, 2nd ed., Taylor & Francis, New York.

[10] Yuan, Z.-X., Tao, W.-Q., and Yan, X. T., 2003, “Experimental Study on Heat Transfer in Ducts with Winglet Disturbances,” Heat Transfer Engineering, Vol. 24(2), pp. 76-84.

BIOGRAPHY OF AUTHOR

R SRINIVAS was born in Kakinada (city), Kakinada (urban mandal) EastGodavari (distict), India, in 1989. He received the B.Tech. degree in Mechanical engineering from the Aditya College of Engineering (Surampalem) under jntu Kakinada, India, in 2011, and Pursuing M. Tech from Aditya college of engineering and technology (jntu Kakinada) In 2014 september.

KOTAMARTHI VIJAY was born in Rajahmundry, East Godavari District, ANDHRA PRADESH India, in 1990. He received the M. Tech degree in thermal engineering from Bonam Venkata Chalamayya Engineering College, Odalarevu, Andhra Pradesh, India, in 2014.He is working as an assistant professor in Aditya college of Engineering & Technology, Surampalem, Andhra Pradesh, India.