Heat Transfer Enhancement in Tube in Tube Heat Exchanger Using Rectangular Wing Type Vortex Generator-A Review

Vitthal Chormale[1], D.D. Palande[2]

[1]PG Student, Department Mechanical Engineering, MCOERC , Nashik, Savitribai Phule Pune University, India
[2]Assoc. Professor, Department Mechanical Engineering, MCOERC, Nashik, SavitribaiPhule Pune University, India

---***---

Abstract-*Vortex generator is responsible for creating the turbulence in the flow of fluid. The experiment is carried out to enhance the heat transfer coefficient with installing the rectangular wing type of vortex generator in tube in tube heat exchanger, these vortex generators are provided on cross shape plate by lancing operation and this cross shape plate is inserted in the test section. These vortex generators cause stream wise longitudinal vortices in the test section which disrupt the growth of the thermal boundary layer and enhances heat transfer rate. Influence of geometrical parameter of rectangular wing vortex generator such as wing height, longitudinal wing pitch and wings attach angle on heat transfer coefficient is studied. Air is taken as the working fluid, the flow regime is assumed to be laminar. By varying the above parameter the heat transfer coefficient is calculated and by comparing all the result optimum size of rectangular wing is achieved.*

***KeyWords*:Vortex generator, Rectangular wing, Heat exchanger, Cross plate, Heat Transfer coefficient.**

1.INTRODUCTION

The process of improving the performance of a heat transfer system is referred as the heat transfer enhancement technique . In order to enhance heat transfer and to improve the thermal performance of the heat exchangers augmentation techniques are widely used. These techniques are classified as Passive Techniques, Active Techniques and Compound Techniques.Passive Techniques are the techniques generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices.Passive techniques promote higher heat transfer coefficient by disturbing or altering the existing flow behavior but they leads to an increase in fluid pressure drop. Some Passive heat transfer enhancement techniques are treated surfaces, rough surfaces, extended surfaces, inserts. Active heat transfer enhancement techniques involves some external power input for the enhancement of heat transfer, examples are mechanical aids, surface vibration, fluid vibration, electrostatic fields, suction and jet impingement. When any two or more techniques employed simultaneously to obtain enhancement in heat transfer that is greater than that produced by either of them when used individually, is termed as compound enhancement.

In this work Tubular or tube in tube heat exchanger is used with a rectangular wing type vortex generator. Tube in tube heat exchangers consist of two tubes, an inner and an outer coiled together. Heat transfer enhancement in tube in tube heat exchanger is possible by providing the vortex generator in inner tube. Types of vortex generator are rectangular wing, rectangular winglet, delta wing, delta winglet and trapezoidal wing. In this study rectangular wing type vortex generator are used. Geometrical parameter of rectangular wing having an influence on heat transfer coefficient and Nusselt number

2. LITERATURE REVIEW

M. Khoshvaght-Aliabadi, S. Zangouei, F. Hormozi [1] studied the CFD and experimental validation for Performance of a plate-fin heat exchanger with vortex-generator channels. A type of plate-fin channel with rectangular wings as a transverse vortex-generator channel was considered. The heat transfer and fluid flow characteristics of the vortex-generator channel were systematically analyzed by 3D-CFD simulations.They studied the influences of seven effective geometrical parameters such as wings height, wings width, channel length, longitudinal wings pitch, transverse wings pitch, wings attach angle, and wings attack angle on the heat transfer rate. By varying this seven geometrical parameters they found that The channel with the rectangular wings increases the heat transfer performance of the Plate fin heat exchanger about 58.3% and 26.2% compared to the channels with the triangular and trapezoid wings, respectively,The heat transfer coefficient and pressured drop values enhance as the wings height, longitudinal wings pitch, and transverse wings pitch decrease and the wings width, channel length, and wings attack angle increase also they developed the Correlations to predict Nusselt number of the conventional working fluids flow such as water, oil, and ethylene glycol inside the Plate fin heat exchanger with vortex-generator channels.

M. Khoshvaght-Aliabadi, F. Hormozi ,A. Zamzamian[2] studied the effects of geometrical parameters on performance of plate-fin heat exchanger and they considered Vortex-generator as core surface and nanofluid as working media in this study. Forced convective heat transfer with laminar and steady-state flow of copper-base deionized water nanofluid inside the vortex-generator plate-fin channels was studied experimentally and also numerically using CFD method. They studied the Influences of two operating factors such as Reynolds number and nanoparticles concentration and seven geometrical parameters which are wing height, wing width, channel length, longitudinal wings pitch, transverse wings pitch, wings attach angle, and wings attack angle on performance of a plate-fin heat exchanger with vortex-generator channels. They developed two correlations for Colburn factor and Fanning friction factor variations based on Reynolds number, nanoparticles weight fraction, and geometrical parameters.

Chi-Chuan Wang, Kuan-Yu Chen, Jane-SunnLiaw, Chih-Yung Tseng [3] worked on a comparative study of the airside performance of fin and tube heat exchangers having plain, louver, and semi-dimple vortex generator . They made eighteen samples and tested with the corresponding fin pitch (Fp) being 1.6 mm and 2.0 mm and the number of tube row (N) are 1, 2 and 4, respectively. Test results indicate that the heat transfer coefficient for N = 1 for louver fin geometry with a smaller fin pitch of 1.6 mm is higher than that of semi-dimple VG and plain fin geometry. For N = 1 with a larger fin pitch of 2.0 mm, the semi-dimple VG is marginally higher than that of louver fin geometry when the frontal velocity is lower than 2 m/s. For the airside performance of N = 2 or N = 4, the heat transfer coefficients for louver fin geometry is about 2–15% higher than those of the semi-dimple VG geometry. The difference is increased with the rising velocity and the results prevail for both fin pitches. However, the difference is smaller at a larger fin pitch due to comparatively effectively swirled motion.

Hung-Yi Li, Ci-Lei Chen, Shung-Ming Chao, Gu-Fan Liang[4] worked on enhancement of heat transfer in a plate-fin heat sink using delta winglet vortex generators. They performed both experiments and simulations to investigate the thermal-fluid characteristics of a flat-fin heat sink with a pair of vortex generators installed in a cross flow channel. The effects of the distance between the trailing edges of the vortex generators, the distance between each vortex generator and the heat sink, the attack angle of the vortex generators, the height of the vortex generators, the configuration of the vortex generators, and the Reynolds number on the thermal-fluid performance of the plate-fin heat sink are elucidated. The results thus obtained revealed that when the distance between the trailing edges of the vortex generators is too small, the thermal performance becomes worse because the air cannot easily flow into the heat sink. Regarding the effect of the position of the vortex generators on thermal performance, the best performance is achieve when the distance between the vortex generator trailing edges equals the length of the heat sink and the distance between the trailing edge of each vortex generator and the front end of the heat sink is zero. An attack angle of the vortex generators of 30° is preferred to optimize the thermal resistance and pressure difference. Although heat transfer increases with the height of the vortex generators, the pressure difference also increases.

M. Hatami, D.D. Ganji, M. Gorji-Bandpy [5] studied the Experimental and thermodynamical analyses of the diesel exhaust vortex generator heat exchanger for optimizing its operating condition. In their research vortex generator heat exchanger is used to recover exergy from the exhaust of diesel engine. Twenty vortex generators with 30° angle of attack are used to increase the heat recovery as well as the low back pressure in the exhaust. The experiments are prepared for five engine loads (0, 20, 40, 60 and 80% of full load), two exhaust gases amount (50 and 100%) and four water mass flow rates (50, 40, 30 and 20 g/s). Finally, a central composite design or CCD analysis is applied on the results to optimize the operating conditions. Results confirm that higher engine loads due to higher gases temperature and larger amount of exhaust gases can enhance the energy recovery due to its ability to more heat transfer to the water.

M. Hatami, D.D. Ganji, M. Gorji-Bandpy [6] studied Experimental investigations of diesel exhaust exergy recovery using delta winglet vortex generator heat exchanger.In their research, a new design of heat exchanger is proposed and designed to recover exergy from exhaust of a diesel engine. Twenty vortex generators with optimum dimensions and angle of attack are located in the exhaust to reach more exergy recovery as well as low pressure drop. The experiments are done in five engine loads (0, 20, 40, 60 and 80% of full load) and four water mass flow rates (20, 30, 40 and 50 g/s). Results show that this heat exchanger has a very low pressure drop and can enhance the heat recovery.

PankajSaha, GautamBiswas, SubrataSarkar [7] studied the Comparison of winglet-type vortex generators periodically deployed in a plate-fin heat exchanger. The objective of their work is assess the performance of a plate-fin heat exchanger with an emphasis on acquiring fundamental understanding of the relation between local flow behavior and heat transfer augmentation mechanism. Numerical simulations are performed in a rectangular channel containing built-in longitudinal vortex generators on the bottom wall arranged periodically both in the streamwise and spanwise directions. Two types of vortex generators, namely, rectangular winglet pair and delta winglet pair with two different flow arrangements, common flow-up and common flow-down have been explored to assess the influence of shape and flow arrangements on heat transfer enhancement. The basic mechanisms of flow structure and heat transfer characteristics have been examined with the help of secondary velocity vectors, streamlines, and temperature contours. They found that During the channel flows, the swirling motions generated by the vortex generators disrupt the thermal boundary layer, intensify mixing and bring about enhancement of heat transfer with relatively less pressure penalty and also Compared to delta winglet pair, rectangular winglet pair produces more heat transfer enhancement and the difference increases with increase in Reynolds number. The CFD configurations provide better heat transfer enhancement as compared to common flow-up configurations.

A.A. Gholami, MazlanA.Wahid, H.A. Mohammed [8] studied the heat transfer enhancement and pressure drop for fin-and-tube compact heat exchangers with wavy rectangular winglet-type vortex generators. They used the rectangular winglets with a particular wavy form for the purpose of enhancement of air side heat transfer performance of fin-and-tube compact heat exchangers. The effect of Reynolds numbers from 400 to 800 and angle of attack of 30° of wavy rectangular winglets are also examined. They found that the wavy rectangular winglet can significantly improve the heat transfer performance of the fin-and-tube compact heat exchangers with a moderate pressure loss penalty.

H.H. Xia, G.H. Tang, Y. Shi, W.Q. Tao [10] worked on Simulation of heat transfer enhancement by longitudinal vortex generators in dimple heat exchangers. They presented double distribution function multi-relaxation-time lattice Boltzmann equation to study the flow and heat transfer in dimple heat exchangers. To enhance the heat transfer with low pressure penalty, a small crescent-shape protrusion was added as a longitudinal vortex generator and a grooved longitudinal vortex generator was developed to reduce the drop loss caused by the crescent-shape protrusion. They got the results which show that the thermal performance of the longitudinal vortex generator cases is higher than that of the dimple cases with similar flow characteristics also from the viewpoint of energy saving, longitudinal vortex generator cases perform better than the dimple cases.

BabakLotfi, BengtSunden, Qiuwang Wang [11] investigated thermo-hydraulic performance of the smooth wavy fin and elliptical tube heat exchangers with vortex generators. They used three types of vortex generators which are rectangular trapezoidal winglet, angle rectangular winglet and curved angle rectangular winglet. They studied the several parameter in this study such as geometric shape of vortex generators, attack angle of vortex generators, placement of vortex generator pairs, tube ellipticity and wavy fin height. The results demonstrate that with increasing Reynolds number and wavy fin height, decreasing the tube ellipticity ratio the heat transfer performance of the smooth wavy fin and elliptical tube heat exchangers is enhanced. The smooth wavy fin and elliptical tube heat exchangers with the advantages of using curved angle rectangular winglet vortex generators and rectangular trapezoidal winglet vortex generators at smaller and larger attack angles, respectively, presents good thermo-hydraulic performance enhancement. Also they proposed new correlations to estimate the values of the average Nusselt number and friction factor based on the Reynolds number, attack angle of vortex generators, tube ellipticity ratio and wavy fin height.

Jin-Sheng Leu, Ying-Hao Wu, Jiin-Yuh Jang [12] studied Heat transfer and fluid flow analysis in plate-fin and tube heat exchangers with a pair of block shape vortex generators. Inclined block shape vortex generators mounted behind the tubes. The effects of different span angles such as 30˚, 45˚ and 60˚ are investigated in detail for the Reynolds number ranging from 400 to 3000. Experiments were carried out by an infrared thermovision and a water tunnel system, respectively, to visualize the temperature distribution and local flow structure. The results indicated that the proposed heat transfer enhancement technique is able to generate longitudinal vortices and to improve the heat transfer performance in the wake regions. The case of span angle is equal to 45˚ provides the best heat transfer augmentation.

Li Li, Xiaoze Du, Yuwen Zhang, Lijun Yang, Yongping Yang [13] studied the numerical simulation on flow and heat transfer of fin-and-tube heat exchanger with longitudinal vortex generators. They investigated heat transfer performance and pressure drop for fin and tube heat exchanger with longitudinal vortex generators numerically. Rectangular and delta winglet pairs were punched on the fin surfaces to enhance the heat transfer of the air-side of the fin and tube heat exchangers. The results showed that the Nusselt numbers increased up to 20% for longitudinal vortex generators on plain fins comparing with plain fins channel without longitudinal vortex generators. The heat transfer enhancement by rectangular winglets was more significant than that of the delta winglets. The rectangular winglet with angle of attack of 25˚ showed the best overall performance than any other angles of attack in rectangular winglets configurations. Also the delta winglet with angle of attack of 45˚ showed the best overall performance than the other angles of attack in delta winglets configurations.

3. SUMMARY

1. Tube in tube heat exchanger with rectangular wing type vortex generator on cross plate having better heat transfer coefficient than with smooth tube
2. The value heat transfer coefficient enhance as the longitudinal wing pitch decreases
3. As the wing attach angle increases the heat transfer coefficient also increases
4. The value heat transfer coefficient increases with the increase in wing height.

REFERENCES

[1] M. KhoshvaghtAliabadi, S. Zangouei, F. Hormozi, “Performance of a plate-fin heat exchanger with vortex-generator channels: 3D-CFD simulation and experimental validation”, International Journal of Thermal Sciences 88 (2015) 180-192.

[2]M. KhoshvaghtAliabadi, F. Hormozi ,A. Zamzamian, “Effects of geometrical parameters on performance of plate-fin heat exchanger: Vortex-generator as core surface and nanofluid as working media”, Applied Thermal Engineering 70 (2014) 565-579.

[3]Chi-Chuan Wang, Kuan-Yu Chen, Jane-SunnLiaw, Chih-Yung Tseng, “An experimental study of the air-side performance of fin-and-tube heat exchangers having plain, louver, and semi-dimple vortex generator configuration”, International Journal of Heat and Mass Transfer 80 (2015) 281–287.

[4]Hung-Yi Li, Ci-Lei Chen, Shung-Ming Chao, Gu-Fan Liang, “Enhancing heat transfer in a plate-fin heat sink using delta winglet vortex generators”, International Journal of Heat and Mass Transfer 67 (2013) 666–677.

[5]M. Hatami, D.D. Ganji, M. Gorji-Bandpy, “Experimental and thermodynamical analyses of the diesel exhaust vortex generator heat exchanger for optimizing its operating condition”, Applied Thermal Engineering 75 (2015) 580-591.

[6]M. Hatami, D.D. Ganji, M. Gorji-Bandpy, “Experimental investigations of diesel exhaust exergy recovery using delta winglet vortex generator heat exchanger”, International Journal of Thermal Sciences 93 (2015) 52-63.

[7]PankajSaha, GautamBiswas, SubrataSarkar, “Comparison of winglet-type vortex generators periodically deployed in a plate-fin heat exchanger – A synergy based analysis”, International Journal of Heat and Mass Transfer 74 (2014) 292–305.

[8]A.A. Gholami, MazlanA.Wahid, H.A. Mohammed, “Heat transfer enhancement and pressure drop for fin-and-tube compact heat exchangers with wavy rectangular winglet-type vortex generators”, International Communications in Heat and Mass Transfer 54 (2014) 132–140.

[9] Leandro O. Salviano, Daniel J. Dezan, Jurandir I. Yanagihara, “Optimization of winglet-type vortex generator positions and angles in plate-fin compact heat exchanger: Response Surface Methodology and Direct Optimization”, International Journal of Heat and Mass Transfer 82 (2015) 373–387.

[10]H.H. Xia, G.H. Tang, Y. Shi, W.Q. Tao, “Simulation of heat transfer enhancement by longitudinal vortex generators in dimple heat exchangers”, Energy 74 (2014) 27e36.

[11] BabakLotfi, BengtSunden, Qiuwang Wang, “An investigation of the thermo-hydraulic performance of the smooth wavy fin-and-elliptical tube heat exchangers

utilizing new type vortex generators'', Applied Energy 75 (2015) 352-262.
[12] Jin-Sheng Leu, Ying-Hao Wu, Jiin-Yuh Jang, "Heat transfer and fluid flow analysis in plate-fin and tube heat exchangers with a pair of block shape vortex generators", International Journal of Heat and Mass Transfer 47 (2004) 4327–4338.
[13]Li Li, Xiaoze Du, Yuwen Zhang, Lijun Yang, Yongping Yang, "Numerical simulation on flow and heat transfer of fin-and-tube heat exchanger with longitudinal vortex generators", International Journal of Thermal Sciences 92 (2015) 85e96.