A Review on Heat Augmentation in Triangular-Fin Heat Exchanger, using Rectangular Wings

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Abstract— The improvement of the performance of heat exchanger with gas as the working fluid becomes particularly important due to the high thermal resistance offered by gases in general. In order to compensate for the poor heat transfer properties of gases, the surface area density of plate heat exchangers can be increased by making use of the secondary fins such as off-set fins, triangular fins, wavy fins, louvered fins etc. In addition, a promising technique for the enhancement of heat transfer is the use of longitudinal vortex generators. The longitudinal vortices are produced due to the pressure difference generated between the front and back surface of vortex generator. The longitudinal vortices facilitate the exchange of fluid near the walls with the fluid in the core and hence, the boundary layer is distributed. It causes the increase in temperature gradient at the surface which leads to the augmentation in heat transfer. An innovative design of triangular shaped secondary fins with rectangular or delta wing vortex generator mounted on their slant surfaces for enhancing the heat transfer rate in plate-fin heat exchanger.
Keywords: Triangular fin heat exchanger, Nusselt Number, Reynolds Number and Triangular Fins, Rectangular Wings

I. Introduction

The triangular fin heat exchanger with delta wing widely used in condensation including partial and reflux condensation, boiling, sublimation and heat or cold storage. This type of extended surface heat exchanger has corrugated fins mostly of triangular or rectangular cross sections sandwiched between parallel plates. The fins may also be incorporated in a flat tube with rounded corners. The parting sheet is usually replaced by a flat tube in the case of liquid or phase change fluid flows on the other side. Most of researcher has worked on compact heat exchanger reformer for high temperature fuel cell system and numerical analysis of instantaneous flow and heat transfer for offset strip fin geometries. Grosse-Gorgemannet showed that the enhancement mechanism by transverse vortex generators need unsteady flow and develop reversed flow regimes which further increase the resistance to flow. Numerically investigation done on the flow structure and heat transfer enhancement in staged row circular tube-fin channel with delta winglet vortex generator mounted on the surfaces. Torri numerically evaluated the delta winglet pair in common flow-up configuration at low Reynolds number to meet the various demands of designers such as compactness, fan power saving and quietness etc. Kwaket experimentally evaluated two to five rows of staggered circular tube bundle with single transverse row of delta winglet in common flow-up configuration placed beside the front row of bundles. For three row bundles, the heat transfer was augmented by 10% to 30% and pressure loss was reduced by 34% to 55% with increase in Renolds number from 350 to 2100. Tiwarie studied numerically the various combinations of the delta winglet pairs in rectangular channel with a built in oval tube. Going through the existing literatures, it was revealed that there are a few investigations on heat transfer coefficients with a combination of longitudinal vortex generators and secondary fins inserts between the parallel plates of a plate-fin heat exchanger

A. *Geometry of Triangular Fin Heat Exchanger:*

Fig. 1 shows geometry of triangular fin heat exchanger with rectangular wings. The dimensions of the triangular fin heat exchanger with rectangular wings are given in table 1.

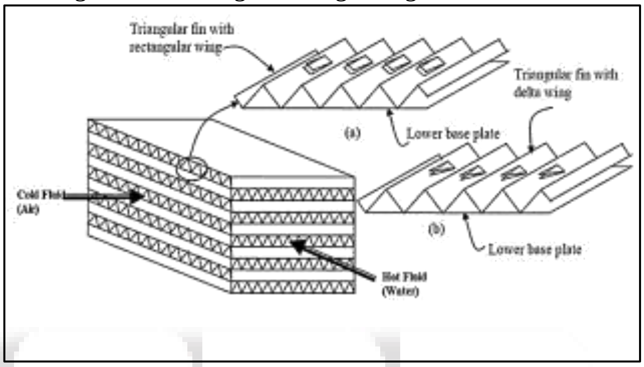

Fig. 1: Triangular Fin Heat Exchanger

Parameter	Symbols	Hot water (W)	Cold Air (a)
Flow length (m)	L	0.1	0.15
Fin Height (mm)	H	5	5
Fin thickness (mm)	T	0.2	0.2
Fin Space (mm)	S	10	10
Number of layers	N	7	10

Table 1: Characteristic dimensions of the triangular fin heat exchanger with rectangular wings.

The basic principles of triangular fin heat exchanger manufacture are the same for all sizes. The corrugations, side-bars, parting sheets

And cap sheets are held together in a jig under a predefined load, placed in a furnace and brazed to form the triangular fin heat exchanger block. The heater tank and nozzles are then welded to the block, taking care that the brazed joints remains intact during the welding process. Differences arise in the manner in which the brazing process is carried out. The methods in common use are salt bath process, the stacked assembly is preheated in a furnace to about 5500C, and then dipped into a bath of fused salt composed mainly of fluorides or chlorides of alkali metals. The molten salt works as both flux and heating agents, maintaining the furnace at a uniform temperature. In case of heat exchanger made of brass, the molten salt removes grease and the tenacious layer of brass oxide, which would otherwise weaken the joints. Brazing takes place in the bath when the temperature is raised above the melting point of the brazing alloy. The brazed block is cleaned of the residual solidified salt by dissolving in water, and then thoroughly dried.

In the vacuum brazing process, no flux or separate pre-heating furnace is required. The assembled block is heated to brazing temperature by radiation from electric heaters and by conduction from the exposed surfaces into the interior of the block. The absence of oxygen in the brazing environment is ensured by application of high vacuum (Pressure 10 – 6 mbar). The composition of the residual gas is further improved (lower oxygen content) by alternate evacuation and filling with an inert gas as many times as experience dictates. No washing or drying of the brazed block is required. Many metals, such as Copper and Brass, Stainless steel, Copper and Nickel alloys can be brazed satisfactorily in a vacuum furnace.

II. EXPERIMENTAL SET-UP

It is cross flow serrated triangular fin heat exchanger consisting of test section, Blower for supplying cold air & water tank for supplying the hot water with in-built heater, water pump and control system. The test section is Brass heat exchanger having length 150 mm and width 100 mm. Calibrated Manometer with flow range 0 to 450 mm is used to measure the flow of cold air & hot water flow is measured from water tank with rotameter. The air at room temperature is drawn from blower. Cold air flow rate is kept constant in seven sets. Two pressure tapping one just before the test section & other just after the test section are attached to U-tube manometer for pressure drop measurement. The mercury (Hg) is used as a monomeric fluid. Four thermocouples measure the inlet & outlet temperature of hot water & cold air (T1, T2, T3 & T4) through a multi-point digital temperature indicator & simultaneously water bath temperature (T5) by using thermocouple which is touched on surface of serrated type triangular fin heat exchanger.

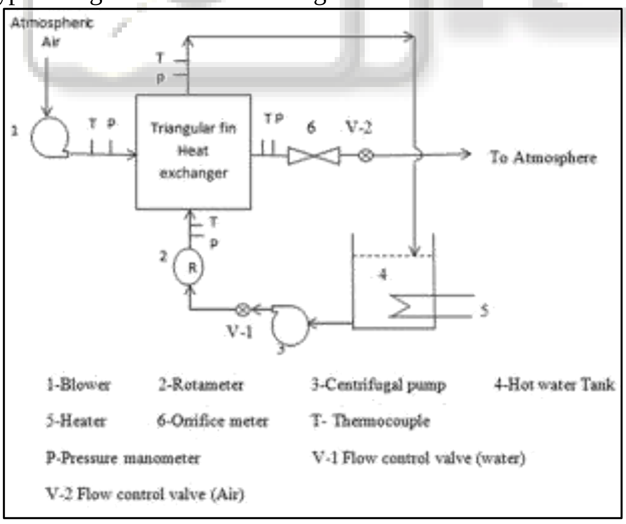

Fig. 2: Flow Diagram of Experimental set up

A. *Test Procedure:*

1) To check the all connections and water level in water tank.
2) To start the heater.
3) To start the motor of blower and pump.
4) To adjust the required flow rates of air and water.
5) To take the readings of temperatures at inlet and outlet of hot fluid and cold fluid.
6) To measure the flow rate of hot and cold fluid.
7) To remove the air bubbles manometer and take readings of pressure drop in hot and cold fluid sides.
8) To repeat the procedure for various flow rate of hot water at constant air flow rate.
9) To repeat the procedure by varying the temperature of hot water at constant air flow rate.
10) To stop the motor and heater.

Parameter	Symbols	Hot water (W)	Cold Air (a)
Flow length (m)	L	0.1	0.15
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Table 2: Range of operating parameters

Analysis of Data Collection: The data were collected from hot and cold fluid side. The operating parameter range is given table 2. Reynolds number can be calculated as

$$Re = \frac{\rho VD}{\mu} \quad (1)$$

Heat Transfer coefficients for the given heat exchanger, (h) were calculated using empirical correlation proposed for cross-flow configuration as

$$Nu = 0.664(Re)^{1/2}(Pr)^{1/3} \quad (2)$$

$$Nu = \frac{hL}{K} \quad (3)$$

Heat Transfer rate is calculated as

$$q = UA\theta_m \quad (4)$$

Pressure drop can be calculated by

ΔP = (Density of Mercury - Density of water)g X h

A_{ff} is free flow cross sectional area which is calculated as follows

A_{ffw} =(hw-tw)(1-tw)La Na

= 5.760 m^2

A_{ffa} =(ha-ta)(1-ta)Lw Nw

= 2.688 m^2

III. RESULT AND DISCUSSION

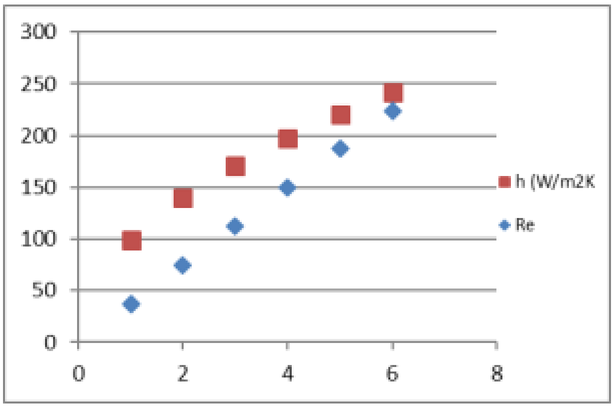

Fig. 3: Reynolds number (Re) vs. Heat transfer coefficient (h) at (55°C & q_{air} = 0.002132 m^3/s)

Figure 3 shows variation if Reynolds number with Heat transfers coefficient for triangular fin heat exchanger at various temperatures (55°C) and air flow (0.002132m^3/s). As found the Reynolds number increases with increasing heat transfer coefficient because as temperature increases pressure drop also increases. And heat transfer coefficient proportional to pressure drop.

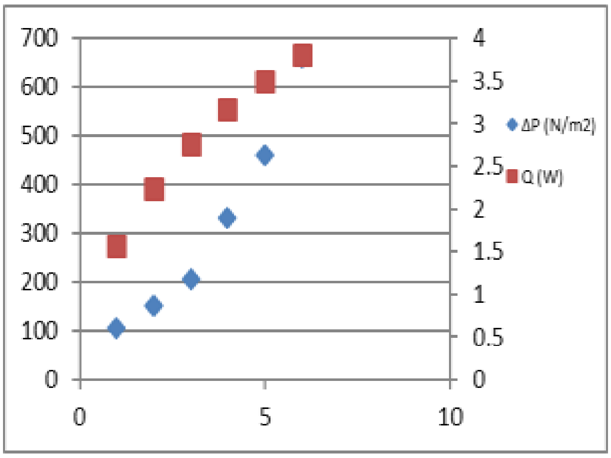

Fig. 4: Reynolds number (Re) vs. Heat transfer coefficient (h) at (55ºC & q_{air} = 0.002132 m^3/s)

Figure 4 shows variation of pressure with Heat transfer rate for triangular fin heat exchanger at various temperatures (55ºC) and air flow (0.002132 m^3/s). As found the pressure drop increases with increasing heat transfer rate because as temperature increases pressure drop also increases. And heat transfer rate proportional to pressure drop.

IV. CONCLUSION

In this study, the heat transfer coefficient and heat transfer rate of triangular plate fin heat exchanger were investigated experimentally. The effect of temperature on heat transfer enhancement and pressure drop behaviors in laminar flow regimes (Re < 200) are described. The test was carried out at different temperatures and flow rate of hot fluid at constant flow rate of cold fluid. Key findings of this study were:

1) An experimental model is established in this study, which can predict the flow and heat transfer characteristics at low Reynolds number.
2) The heat transfer coefficient and heat transfer rate increases with increasing Reynolds number and pressure drop.
3) As the Reynolds number increases the pressure drop and heat transfer rate also increases.
4) There is a significant offset between trends of triangular fins by obtaining existing the empirical correlations and experimental data at Re < 200

REFERENCES

[1] Grosse-Gorgemann, A., Hahne, W., and Fiebig, M., "Influence of Rib Height on Oscillations, heat Transfer and Pressure Drop in Laminar Channel Flow," Proceedings of Eurotherm 31, Vortices and Heat Transfer, Bochum, Germany, 1993, pp 36-41
[2] Biswas 31, g., Mitra, N. K. and Fiebig, M., " Heat Transfer Enhancement on Fin-Tube Heat Exchanger by Winglet Type Vortex generators," International Journal Of Heat and Mass transfer, Vol. 37, 1994 pp. 283-291.
[3] Fiebig, M., Grosse-Gorgemann, A., hahne, W., Leiner, W., Mitra, N.K., and Weber, D., "Local Heat transfer and Flow Strructure in Grooved Channels, Measurements and Computations," Proceedings of the Tenth International Heat Transfer Conference , Brighton, UK,Vol.4,1994 pp.237-242.
[4] K.Torii, K.M. Kwak, K Nishino, "Heat transfer enhancement accompanying pressure-loss reduction with winglet type vortex generators for fin-tube heat exchangers", Int.J. Heat Mass Transfer 45 2002, 3795-3801.
[5] Kwak K.M., Torii,K., and Nishino,K.," Heat Transfer and Pressure Loss Penalty for the Number of Tube Rows Of Staggered Finned-Tube Bundles with a Single Transverse Row of Winglets," International journal of Heat and Mass Transfer, Vol. 46, 2003, pp. 175-180.
[6] Tiwari, S., Maurya, D., Biswas, G., and Eswaran, V., "Heat transfer Enhancement in Cross Flow Heat Exchangers using Oval Tubes and Multiple Delta Winglets," International Journal of Heat and Mass Transfer, Vol. 46, 2003, pp. 2841-2856.
[7] Pesteei, S. M., Subbarao, P. M. V., and Ararwal, R. S., " Experimental study of the Effect of Winglet Location on Heat Transfer Enhancement and Pressure Drop in Fin-Tube Heat Exchanger," Applied Thermal Engineering, Vol. 25, 2005, pp.1684-1696.
[8] Lawason, M. J., and Thole K. A., " Heat Transfer Augmentation along the Tube Wall of a Louvered Fin Heat Exchanger using Practical Delta Winglets," International Journal of Heat and Mass Transfer, Vol. 51, 2008, pp. 2346-2360.
[9] Chang, L. M., Wang, L.B., Song, K. W., Sun, D.L., and Fan, J.F., " Numerical Study of the Relationship Between Heat Transfer Enhancement and Absolute Vorticity Flux along Main Flow Direction in a channel Formed by a Flat Bank Fin with vortex Generators," International Journal of Heat and Mass Transfer, Vol. 52, 2009, pp. 1794-1801.
[10] R. K. Shah and A. C. Mueller, "Heat Exchanger," in Ullmann's Encyclopedia of Industrial Chemistry, Unit Operation II, Vol. B3, Chapter 2, 2-1-2-108 VCH Publishers, Washington, 2013.