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Experimental Investigation of Heat Transfer in Modified Finned Tube Banks Arrangement with in-Line and Staggered Layout

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***Abstract*— One of the most common equipment that are used in all types of power plants and engines are heat exchangers. FTHEs are widely used in various applications, e.g. ventilating and air-conditioning systems, refrigeration, and car radiators etc. as they own high performance and low space requirement. In this study, the characteristics of the forced convective heat transfer and pressure drop in both inline and staggered arrangements of circular fin cross flow heat exchanger are Experimentally investigated and the effect of mass flow rate on parameters such as Nusselt number, overall heat transfer coefficient, and heat transfer is studied. The air was blown with the velocities 0.2m/s, 1m/s, and 2.3m/s and the corresponding changes in inlet and outlet temperature of hot and cold air was measured. It was found that the Heat transfer (Q), Heat transfer coefficient(h), and Nusselt number(Nu) all increase with the increase in mass flow rate for both the inline and staggered arrangement and inline arrangement results in better heat transfer in this case.**

***Index Terms*— heat exchangers, Nusselt number, Heat transfer coefficient, inline and staggered arrangement**

1.INTRODUCTION

The fin geometry has become as increasingly important factor in the design of a plate-and-fin heat exchanger. The high-performance offset strip, wavy and louver fins provide quite high heat transfer coefficients for gases and two-phase applications. It offers significant advantages like lower gas pressure drop than circular tube designs and the ability to have the fins normal to the gas flow over the full gas flow depth over the traditional fin-and-round tube geometry. Enhanced surface geometries are widely used with liquids for cooling electronic equipment. The typical extended surfaces used for the plate-and-fin heat exchangers are plain fin, wavy fin, offset strip fin, louvered fin, perforated fin, etc. Based on the tube arrangement, these types of heat exchangers can further be divided in two different groups such as staggered and inclined arrangement. Plate fin-and-tube heat exchangers of plain fin pattern are commonly used in the process and HVAC&R (Heating, Ventilating, air conditioning, and refrigeration) industries. The plain plate fin configuration is the most popular fin pattern, owing to its simplicity, durability, and versatility in application. When the fins have periodic corrugations in their geometry in the form of a wave, then it is called a wavy fin. The wavy pattern may be smooth or of a herringbone pattern. These periodic corrugations having a definite angle of corrugation that helps in better mixing of flow, thereby providing higher heat transfer. These corrugations in a wavy fin help in increasing the flow length in a limited space than that of the plain fin. The perforated fin is manufactured by punching a pattern of spaced holes in the fin material before it is folded to form the V-shaped flow channels. If the porosity of the resulting surface is sufficiently high, heat transfer enhancement can occur due to the boundary layer dissipation in the wake region formed by the holes.

2. LITERATURE REVIEW

In general, a lot of work on heat exchanger is successfully done; still a lot of work has to be done. The work already done on the topic is presented below:

2.1 PRESSURE DROP AND HEAT TRANSFER CHARACTERISTICS

Arafat A. Bhuiyan (2013) investigated heat transfer and fluid flow characteristics of a four-row plain fin-and-tube heat exchanger using the Commercial Computational Fluid Dynamics Code ANSYS CFX 12.0. Heat transfer and pressure drop characteristics of the heat exchanger are investigated for Reynolds numbers ranging from 400 to 2000.

From the early literature on the experimental analysis of thermal–hydraulic performance of Copper–water nano-fluid flow in different plate-fin channels presented by M. Khoshvaght Aliabad (2014) et al., fabricated and tested seven plate-fin channels, including plain, perforated, offset strip, louvered, wavy, vortex generator, and pin. The fluid used for testing was copper–water nano-fluids.

Experimental study on thermal hydraulic performance of a wavy fin-and-flat tube aluminium heat exchanger presented by Junqi Dong (2013) et al., in this experimental investigation a 16 samples with different geometry parameters were tested and the effects of fin height, fin pitch, fin length, wavy amplitude, and wavy length on the heat transfer and pressure drop were studied. Experimental and numerical investigation of thermal -hydraulic performance in wavy fin-and-flat tube heat exchangers presented by Junqi Dong (2016) et al., experimentally investigated the air flow and heat transfer characteristics over the wavy fin heat exchangers and the results of friction factor and heat transfer performance test data are for fully developed turbulent region of air flow in the wavy fin.

Jose Fernandez-Seara (2013) et al., investigated on the pressure drop and heat transfer characteristics of a titanium brazed plate-fin heat exchanger with offset strip fins by using firstly water on both sides of the heat exchanger and secondly 10-30 wt% ethylene glycol aqueous solutions as working fluids and both the results were compared.

Giovanni lozza (2005) et al., showed the performance of various fin configurations in air cooled condenser and liquid coolers to enhance the heat transfer capabilities of the devices the results showed louvered fin geometry had the best heat transfer rate but the pressure drop was high.

S.M. Pesteei (2005) et al., investigated experimentally study of the effect of winglet location on heat transfer enhancement and pressure drop in fin-tube heat exchangers the results showed a reasonable amount of increase in the heat transfer with addition of winglet type vortex generators.

Ting Ma (2011) et al., conducted an experimental study on investigation of a novel bayonet tube high temperature heat exchanger with inner and outer fins where the numerical results showed that the inner fins and inner tube both should not be welded together and the mass flow rate and the inlet temperature on the fuel gas side have a reasonable effect on the heat transfer rate and effectiveness, and the pressure drop ratios are mainly affected by the mass flow rate rather than the inlet temperature. Design and experimental analysis of spiral tube heat exchanger by Jay.J. Bhavsar (2013) et al., a spiral tube heat exchanger was fabricated and experimental analysed and was compared with a shell and tube heat exchanger and the results showed the spiral tube heat exchanger had a better heat transfer rate with an increase in pressure drop compared to shell and tube heat exchanger. Performance analysis of cross flow plate fin heat exchanger for Immiscible system using ANN by M. Thirumarimurugan (2010) et al., the results such effectiveness and overall heat transfer were obtained experimentally and simulation results were also obtained by using ANN general regression it showed the predicted results obtained by the ANN approach are close to the experimental results. Experimental determination of correlations for mean heat transfer coefficients in plate fin and tube heat exchangers by Dawin taler (2012) experimental determined the heat transfer coefficient for a cross flow plate fin and tube heat exchanger and correlation were developed for the this type of heat exchanger the result show increase in heat transfer and as well as increase in pressure drop.

Vaisi (2011) et al., carried out an experimental investigation of geometry effects on the performance of a compact louvered heat exchanger in which the results indicated that the configuration of the louvered fins has the dominant influence on the heat transfer and pressure drop from that louver fin. The test setup is shown in Fig.2.4. Heat-transfer enhancement in fin-and-tube heat exchanger with improved fin design by Mao-Yu Wena (2009) et al., showed the study of use of the compounded fin constructed for heat exchanger. Results of the compounded fin had an increase in heat transfer and pressure drop, f factor and j factor compared to the flat fin heat transfer coefficient

Role of channel shape on performance of plate-fin heat exchangers. Experimental assessment by M. Khoshvaght- Aliabadi (2014) et al., carried out a comparison study on seven common configurations of channels used in plate-fin heat exchangers .All the channels, including plain, perforated, offset strip, louvered, wavy, vortex-generator, and pin, were fabricated and tested experimentally. The working fluid was water. The results showed that the vortex generator channel has a significant enhancement in the heat transfer coefficient and a proper reduction in the heat exchanger surface area. An experimental investigation of heat transfer and friction losses of interrupted and wavy fins for fin and tube for fin and tube heat exchanger by Giovanni lozza (2001) et al., conducted an experimental study on a pin fin heat exchanger used in air cooled and liquid cooler condensers with different fin configuration like flat, wavy and louvered fins. All the fins geometries were compared by experimental data and the results showed a better heat transfer and pressure drop enhancement when louvered fins compared to flat and wavy fins. Performance evaluation of wire spring fin for compact plate fin heat exchangers by H. Iwai (2005) et al., suggested a usage of thin metal wire structure as a new type of extended heat transfer surface the fin was used in a plate fin heat exchanger at low Reynolds number between 100 to 1000 and heat transfer was evaluated and the result showed a better heat transfer compared a offset fin plate fin heat exchanger. Yonghan Kim (2005) et al., experimental investigated on heat transfer rate of flat plate finned tube heat exchangers with large fin pitch in this experiment a total of 22 heat exchangers were tested with different fin pitch tube and number of tube rows and tube alignment. The experimental setup is shown in Fig. 2.7. The results showed with the increase in fin pitch and tube row there is a decrease in heat transfer. The decrease in the heat transfer is approximately 10 %.

Praveen Pandey (2012) at el., carried an experimental investigation on the effect of fin pitch on the performance of plate type fins the experiment was conducted for different pitch settings, three types of fins were used for this experiment the experiment was conducted in both free and force convection. And the results show there is increase in heat transfer coefficient with decrease in fin base temperature and there is significant effect on the performance of heat exchanger with change in fin pitch. Effect of fin pitches on the optimum heat transfer performance of crimped spiral fin-and-tube heat exchangers by Parinya Pongsoi (2014) et al., carried out various experiments to optimize the fin pitch for a crimpled spiral fin and tube heat exchanger. The test setup is shown in Fig. 2.8. The size of the fin was varied from 2.4-6.5 mm. The flow arrangement used is parallel cross flow is combined with counter cross flow in a two-row configuration. The results show a low convective heat coefficient at the size 2.4 and the optimum pitch for this experiment is 4.2 mm.

Performance investigation of an innovative offset strip fin arrays in compact heat exchangers by Hao Peng (2014) et al., carried out experimental investigation with five different set arrays of offset fins with various air velocities with a constant inlet steam pressure. The experimental results indicated that the fin pitch, fin length and fin bending distance have a significant influence on thermal performance of fins. The main conclusion obtained from this work is it will be helpful for future development and design of high-efficiency heat exchangers involving offset strip fin structures.

2.2 FLOW PATTERNS

Sedat Yayla (2005) conducted an experimental investigation on flow characteristic of staggered multiple slotted tubes in the passage of a fin tube heat exchanger a particle flow velocimetry (PIV) was used to study the specified flow filed and time averaged flow data was collected and was presented graphical for a fin tube heat exchanger and the result showed a three dimensional and complex flow behaviour in the heat exchanger.

Anjun jiao (2005) et al., carried out an experimental analysis on Effects of distributor configuration on flow maldistribution in plate-fin heat exchangers in which the effects of distributor parameters on fluid flow in plate fin heat exchanger was completed experimentally. The results showed that the flow maldistribution plays a significant role in optimizing the structural design and also improve the performance of a plate fin heat exchanger. The experimental setup is shown below Fig. 2.9.

Masoud Asadi (2013) et al., investigated on the effects of mass flow rate in terms of pressure drop and heat transfer characteristics the results indicated that as the mass flow increases the heat transfer and pressure drop also increases and the optimum mass flow rate depend on the dimensions of the heat exchanger. Experimental investigation of header configuration on flow misdistribution in plate-fin heat exchanger by Anjun Jiao (2003) et al., showed that the performance of flow distribution in PFHE is effectively improved by the optimum design of the header configuration.

3. METHODOLOGY AND EXPERIMENTATION

The experimental study is done in two arrangements of pipe inline and staggered of heat exchanger (fig 4.1) having the specifications as listed below: -
Specifications of Heat Exchanger:
Pipe diameter= 12.7mm
Material of construction of tube= Copper
Pipe length= 530 mm
Fin material- copper
The cold air is blown with the use of blower at different velocities outside the pipe while the hot air flows inside the pipe. In this work, the velocity of the cold air blowing through the blower was varied which leads to the change in temperature of the air inside and outside the pipe. The air was blown with the velocities 0.2m/s, 1m/s, and 2.3m/s. The inlet air temperature and the temperature difference between inlet and outlet through the test core are measured by thermometer.

4. RESULT

The present study is performed on two arrangements of heat exchanger i.e. inline and staggered arrangements.

4.1 TEMPERATURE

The temperature of the hot and cold air at the inlet and outlet are tabulated below.

Table 4.1 For inline arrangement

velocity	T_{hi}(ºC)	T_{ho}(ºC)	T_{ci}(ºC)	T_{co}(ºC)
0.2	79.6	73.3	33.3	35.1
1	82.9	76.4	35.9	36.9
2.3	87.4	74.9	37.4	38.9

Table 4.2 For staggered arrangement

velocity	T_{hi}(ºC)	T_{ho}(ºC)	T_{ci}(ºC)	T_{co}(ºC)
0.2	102	47.4	36.6	39
1	104.5	48.2	37.5	38.45
2.3	108	49.6	39.87	41.27

The Nusselt number, heat transfer and convective heat transfer coefficient are calculated, and plotted below.

4.2 INLINE ARRANGEMENT

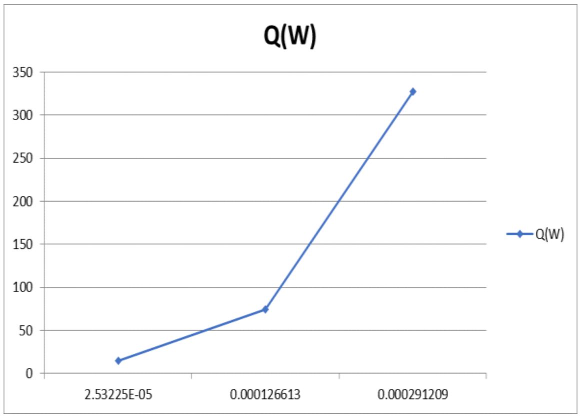

Fig 4.1. Variation of mass flow rate vs total heat transfer of INLINE heat exchanger

From above graph it can be seen that the total heat transfer is increasing rapidly with increasing the mass flow rate.

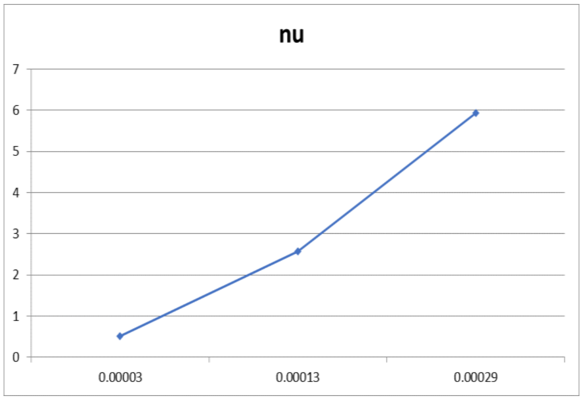

Fig 4.2. Variation of mass flow rate vs nusselt number of INLINE heat exchanger

From above graph it can be seen that the Nusselt number is increasing with increasing the mass flow rate.

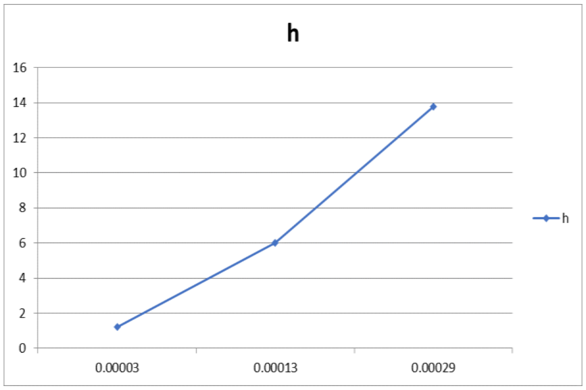

Fig 4.3. Variation of mass flow rate vs heat transfer coefficient of INLINE heat exchanger

From above graph it can be seen that the heat transfer coefficient is increasing with increasing the mass flow rate.

4.3 STAGGERED ARRANGEMENT

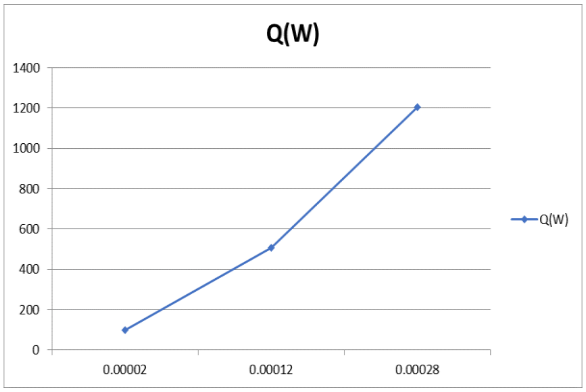

Fig 4.4. Variation of mass flow rate vs total heat transfer of Staggered heat exchanger

From above graph it can be seen that the total heat transfer of Staggered heat exchanger is increasing with increasing the mass flow rate

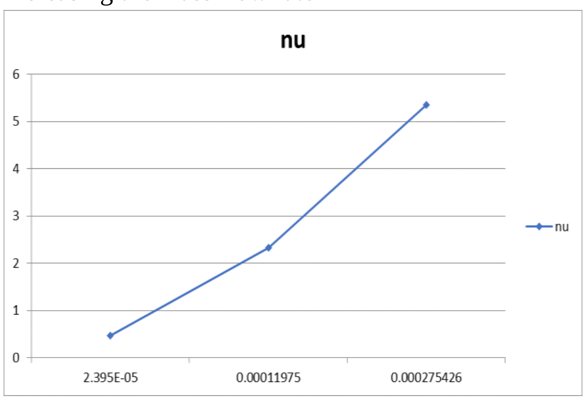

Fig 4.5. Variation of mass flow rate vs nusselt number of staggered heat exchanger

From above graph it can be seen that the Nusselt number is increasing with increasing the mass flow rate.

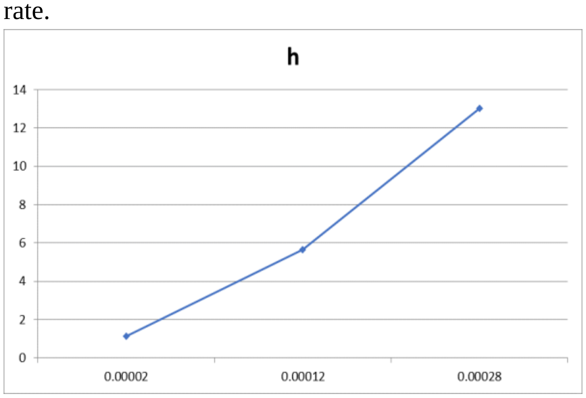

Fig 4.6. Variation of mass flow rate vs heat transfer coefficient of staggered heat exchanger

From above graph it can be seen that the heat transfer coefficient is increasing with increasing the mass flow rate.

4.4 COMPARISON OF BOTH ARRANGEMENTS

Heat transfer

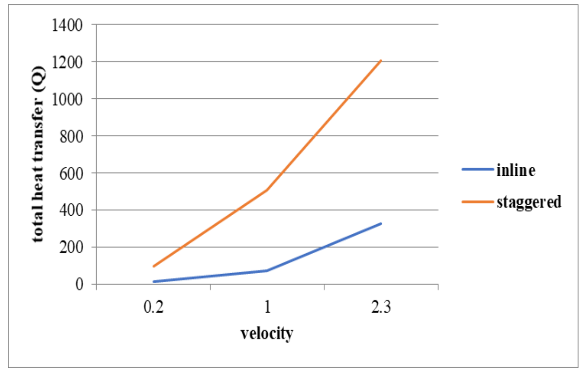

Fig 4.7 Total Heat Transfer Comparison for Inline and Staggered Arrangement

From above graph it can be seen that the Heat transfer is increasing with increasing the mass flow rate. The inline arrangement is better at transferring heat when compared to staggered arrangement.

Total Nusselt number

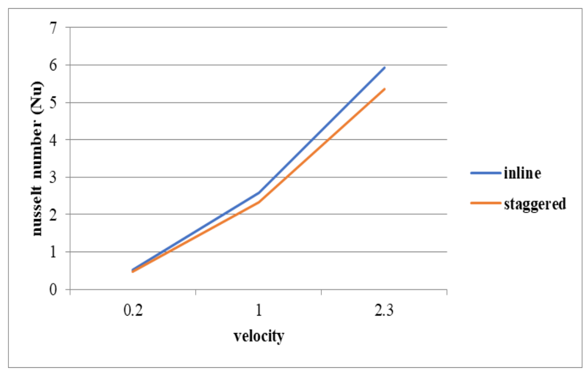

Fig 4.8 Total Nusselt number Comparison for Inline and Staggered Arrangement

From above graph it can be seen that the Nusselt number is increasing with increasing the mass flow rate. The Nusselt number is slightly more in inline arrangement that staggered arrangement.

Heat transfer coefficient

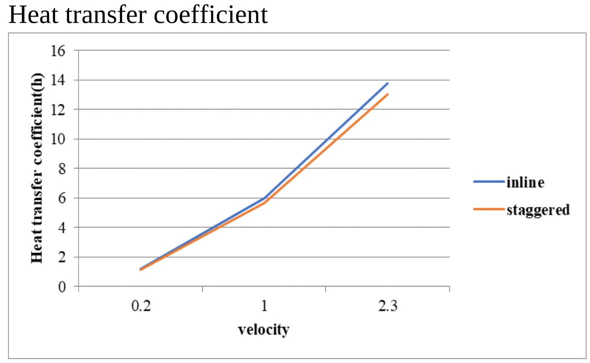

Fig 4.9 Total Heat transfer coefficient Comparison for Inline and Staggered Arrangement

From above graph it can be seen that the Heat transfer coefficient is increasing with increasing the mass flow rate. The Heat transfer coefficient is slightly more in inline arrangement than staggered arrangement.

5. CONCLUSION

In this study, a parametric study is performed to investigate the effects of mass flow rate on the different parameters such as heat transfer (Q), Heat transfer coefficient(h), and Nusselt number(Nu) of cross flow heat exchanger.

It is concluded that

1. Heat transfer (Q), Heat transfer coefficient(h), and Nusselt number (Nu) all increase with the increase in mass flow rate for both the inline and staggered arrangement
2. The inline arrangement results in better heat transfer, and value of Heat transfer coefficient(h), and Nusselt number (Nu) is also more.

Note: The inline arrangement is resulting in better heat transfer as the number of tubes in inline is taken 6 while in stagger arrangement it is 5.

REFERENCES

[1] Arafat A. Bhuiyan Three-dimensional performance analysis of plain fin tube heat exchangers in transitional regime, Applied Thermal Engineering, 50, 445-454, 2013.

[2] M. Khoshvaght- Aliabadi, F. Hormozi, A. Zamzamian, Experimental analysis of thermal–hydraulic performance of copper–water nano-fluid flow in different plate-fin channels Experimental Thermal and Fluid Science 52, pp. 248–258, 2014.

[3] W.S. Kuo, Y.M. Lie, Y.Y. Hsieh, T.F. Lin, Condensation heat transfer and pressure drop of refrigerant R -410A flow in a vertical plate heat exchanger, International Journal of heat and mass transfer, 48, pp.5205-5220, 2005.

[4] S.M. Pesteei, P.M.V. Subbarao, R.S. Agarwal, Experimental study of the effect of winglet location on heat transfer enhancement and pressure drop in fin-tube heat exchangers, Applied Thermal Engineering, 25, pp.1684–1696, 2005.

[5] Ting Ma, Min Zeng, Yanpeng Ji, Haibin Zhu, Qiuwang Wang, Investigation of a novel bayonet tube high temperature heat exchanger with inner and outer fins, International Journal of Hydrogen Energy, 36, pp. 3757- 3763, 2011.

[6] Jay J. Bhavsar, V K. Matawala, S. Dixit, Design and experimental analysis of spiral tube heat exchanger, International Journal of Mechanical and Production Engineering, Volume-1, Issue-1, pp. 2320-2092, 2013.

[7] M. Thirumarimurugan, T. Kannadasan, S. Gopalakrishnan, Performance analysis of cross flow plate fin heat exchanger for immiscible system using ANN, International Journal of Chemical and Environmental Engineering, Volume-1, No.1, 2010.

[8] A.Vaisi, M. Esmaeilpour and H. Taherian, Experimental investigation of geometry effects on the performance of a compact louvered heat exchanger, Applied Thermal Engineering 31, pp. 3337-3346, (2011).

[9] Mao-Yu Wena, Ching-Yen Ho, Heat-transfer enhancement in fin-and-tube heat exchanger with improved fin design, Applied Thermal Engineering 29, pp.1050–1057, (2009).

[10] M. Khoshvaght-Aliabadi, F. Hormozi, A. Zamzamian "Role of channel shape on performance of plate-fin heat exchangers: Experimental assessment" International Journal of Thermal Sciences 79, pp. 183-193, (2014).

[11] Giovanni lozza and Umberto Merlo. ―An experimental investigation of heat transfer and friction losses of interrupted and wauy fins for fin and tube heat exchanger, International Journal of refrigeration 24, pp.409-416, (2001).

[12] H.Iwai, S Kawakami, K.Suzuki, J.Sujii, T.Abiko, Performance evaluation of wire spring fin for compact plate fin heat exchangers, Enhanced Compact and Ultra-Compact Heat Exchangers, Science, Engineering and Technology, CHE2005-21 (2005).

[13] Yonghan Kim and Yongchan Kim, Heat transfer characteristics of flat plate finned-tube heat exchangers with large fin pitch, International Journal of Refrigeration 28, pp. 851–858, (2005).

[14] Praveen Pandey, Rozeena Praveen, S. N. Mishra ―Experimental investigation on the effect of fin pitch on the performance of plate type fins, IJRET, Volume: 1 Issue: 3, pp. 382-388. (2012).

[15] Awais, Muhammad, and Arafat A. Bhuiyan. "Enhancement of thermal and hydraulic performance of compact finned-tube heat exchanger using vortex generators (VGs): a parametric study." International Journal of Thermal Sciences 140 (2019): 154-166.

[16] Fugmann, Hannes, Lena Schnabel, and Bettina Frohnapfel. "Heat transfer and pressure drop correlations for laminar flow in an in-line and staggered array of circular cylinders." Numerical Heat Transfer, Part A: Applications 75, no. 1 (2019): 1-20.

[17] Mangrulkar, Chidanand K., Ashwinkumar S. Dhoble, Pawan Kumar Pant, Nitin Kumar, Ashutosh Gupta, and Sunil Chamoli. "Thermal performance escalation of cross flow heat exchanger using in-line elliptical tubes." Experimental Heat Transfer (2019): 1-26.

[18] Li, Xiuzhen, Dongsheng Zhu, Yingde Yin, Aimin Tu, and Shijie Liu. "Parametric study on heat transfer and pressure drop of twisted oval tube bundle within line layout." International Journal of Heat and Mass Transfer 135 (2019): 860-872.

[19] Khalaji, Mansour Nasiri, Isak Kotcioglu, Sinan Caliskan, and Ahmet Cansiz. "The second law analysis of thermodynamics for the plate–fin surface performance in a cross-flow heat exchanger." Journal of Heat Transfer 141, no. 1 (2019).

[20] Ke, Hanbing, Tariq Amin Khan, Wei Li, Yusheng Lin, Zhiwu Ke, Hua Zhu, and Zhengjiang Zhang. "Thermal-hydraulic performance and optimization of attack angle of delta winglets in plain and wavy finned-tube heat exchangers." Applied Thermal Engineering 150 (2019): 1054-1065.

[21] Modi, Ashish J., and Manish K. Rathod. "Comparative study of heat transfer enhancement and pressure drop for fin-and-circular tube compact heat exchangers with sinusoidal wavy and elliptical curved rectangular winglet vortex generator." International Journal of Heat and Mass Transfer 141 (2019): 310-326.

[22] Wang, Pengfei, Jin Jiang, Shunyang Li, Xiangyu Luo, Shaojie Wang, and Wensheng Zhao. "An investigation of influence factor including different tube bundles on inclined elliptical fin-tube heat exchanger." International Journal of Heat and Mass Transfer 142 (2019): 118448.

[23] Han, Hui, Shaowei Wang, Li Sun, Yuxing Li, and Shuo Wang. "Numerical study of thermal and flow characteristics for a fin-and-tube heat exchanger with arc winglet type vortex generators." International Journal of Refrigeration 98 (2019): 61-69.

[24] Ibrahim, Emad Z., Mohamed A. Essa, Mostafa M. Ibrahim, and Mohamed N. El-Sayed. "Heat Transfer Enhancement and Flow Structure in Heat Exchanger Tube by Using In-Line And Staggered Discrete Ribs Arrangements." Journal Homepage: www. feng. bu. edu. eg 1, no. 39 (2019): 79-85.