Experimental Analysis for Counter to Cross Flow Air Cooled Heat Exchanger in Concentric Tube by Rectangular Copper Fins with Internal Spiral Grooving

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Abstract

In this manuscript we have presented eight variation of Air-Cooled Heat Exchanger (ACHE) design with internal grooving, all of them are having variable number of copper fins with different distances between the fins. In the proposed design we get the value of heat transfer rate of a counter to cross flow ACHE is 7833.77 watt, 4068.13 watt, 2736.95 watt, 2161.49 watt, 1802.89 watt, 1546.44 watt, 1336.51 watt and 1165.74 watt in natural convection (without fan) for 5 millimeters, 10 millimeters, 15 millimeters, 20 millimeters, 25 millimeters, 30 millimeters, 35 millimeters and 40 millimeters respectively. Then again, value of rate of heat transfer in forced convection (with fan) are 8007.46 watt, 4084.81 watt, 2754.69 watt, 2205.98 watt, 1809.24 watt, 1555.39 watt, 1352.88 watt and 1172.78 watt for 5 millimeters, 10 millimeters, 15 millimeters, 20 millimeters, 25 millimeters, 30 millimeters, 35 millimeters and 40 millimeters respectively.

Keywords: Air-cooled heat exchanger (ACHE), Rate of heat transfer, Thermal efficiency of ACHE, Internal grooving, Rectangular copper fins.

I INTRODUCTION

A heat exchanger is a whole system which is highly utilized for transferring thermal energy (heat) between different fluids [1,2], between fluid and solid particulates or even between a fluid and solid surface, at various working temperatures under the environment of thermal contact. Commonly, there are no external heat and work trades in heat exchangers. In previous time, heating or cooling of a liquid stream for single or multi component liquid streams were involved. In different applications, the objective might be to improve or fractionate, or discard heat, or spay, or concentrate sterilize, refine, crystallize, or might be to control a process fluid. If we generalized the heat exchanger most of them are designed in such a way that the fluids exchanging heat between the surfaces with direct contact. Mostly in these kind of direct surface contact heat exchangers the transfer of heat between different fluid takes place through a separating wall or even into and out of a wall in a transitory manner so that heat transfer take place in controlled way and the fluid could not mixed or even leak. So, as per the definition, we can see that such exchangers [3,4] are stated to as direct transfer type.

And on the other hand, indirect transfer type consists of exchangers in which there are discontinuous heat exchanges between the hot and cold fluid using the concept of thermal energy storages or released by the heat exchangers surface or medium are stated as the indirect heat transfer type exchanger, or fundamentally called regenerators. These classes of heat exchangers are typically have fluid outflow from one to another fluid streams because of the fact that the pressure difference between matrix rotation, switching or even valve. Some of the very well-known examples of heat exchangers [5,6] are radiators of automobile, shell or type tube exchangers, cooling towers, air preheaters, evaporators and condensers. At present heat exchangers are available in many configurations. Some of the most used heat exchanger classification is as follows:

(1) Classification Based on Transfer Processes
   a. Indirect-Contact Heat Exchangers
   b. Direct-Contact Heat Exchangers
(2) Classification Based on Number of Fluids
(3) Classification Based on Compactness of Surface
   a. Gas to Fluids heat Exchanger
   b. Liquids to Liquid and Phase changing heat Exchanger
(4) Classification Based on Construction Features
   a. Tub based Heat Exchangers
   b. Plate-based Heat Exchangers
   c. Extended Surface based Heat Exchangers
   d. Regenerators type Heat Exchangers
(5) Classification Based on Flow of Liquid Arrangements
   a. Single Pass flow based heat Exchangers
   b. Multipass flow based heat Exchangers
(6) Classification Based on Transfer of Heat Mechanisms based heat Exchangers

Materials play very important role in the designing of heat exchanger [7,8] and defining its performance parameters such as heat transfer rate. There are several material tools used to improve the performance of heat exchangers such as internal and external grooving, shape of grooving profile [9,10] such as circular, rectangular etc. [4,5]. To get enhanced performance of heat exchangers a universal method can be used of different materials which are by placing on different pitch can affect the heat transfer rates of heat exchangers. In the proposed work we are taking 8 variation of fin pitch viz. 5 millimeters, 10 millimeters, 15 millimeters, 20 millimeters, 25 millimeters, 30 millimeters, 35 millimeters and 40 millimeters respectively with varying fins (200 to 25).

The respite of the paper is prearranged in four sections. Section II is used to describe all of the eight proposed design with its dimension. Section III presents the various results based on performance parameters [11,12,13] such as heat transfer rate, overall fin efficiency, capacity ratio

(C), effectiveness of cross flow ACHE, number of transfer unit (NTU) as a final point a conclusion is presented in Section IV with best proposed design.

II DESIGN

In this section, we present the proposed design with eight variations is fin distance with rectangular copper fin of thickness of 0.5 mm, height = 6.4 cm and length = 11.2 cm, calculated using standard formulas is shown in fig. 1.

Here we use internal spiral grooving in a concentric tube with radius of 3 mm and pitch length of 6 mm on aluminum material [12,13] and variable copper fins for the proposed heat exchanger. Dimension of the proposed design has outer wall thickness of 3 mm while inner wall thickness of 3 mm with internal diameter of 26 mm and outer diameter of 32 mm respectively as shown below (fig 2). The overall length of the proposed tube is again 1 meter standard dimension.

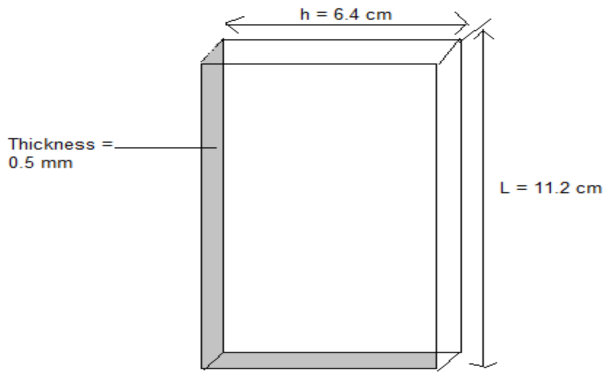

Figure1: Layout of rectangular copper fin of proposed heat exchanger.

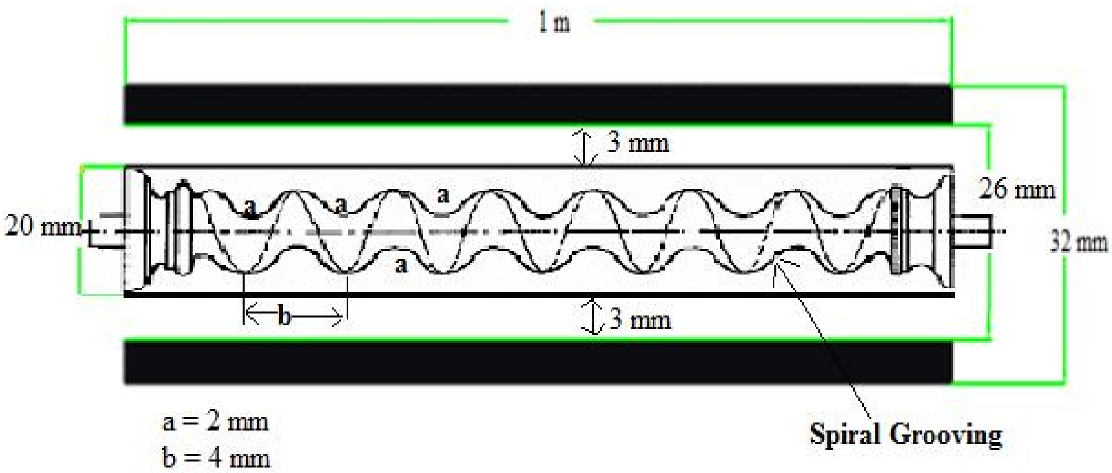

Figure 2: Layout of concentric tube heat exchanger with internal spiral grooving.

By changing the fins pitch with changing number of copper fins in proposed concentric tube heat exchanger in order to get the most enhanced design in terms of performance as well as cost, for that we are taking eight variation in successive rectangular fin to evaluate the performance of heat transfer efficiency [13,14] of the proposed heat exchanger by changing the distance of fins. The proposed distance between the fins are 5 millimeters, 10 millimeters, 15 millimeters, 20 millimeters, 25 millimeters, 30 millimeters, 35 millimeters and 40 millimeters in 8 proposed setup for the ACHE with 200, 102, 68, 52, 42, 35, 29 and 25 fins respectively. This is demonstrated with the help of Fig. 3, here “N” represents the number of fin used for different proposed setup its value depends on the value of “d” which is the distance between two successive fins.

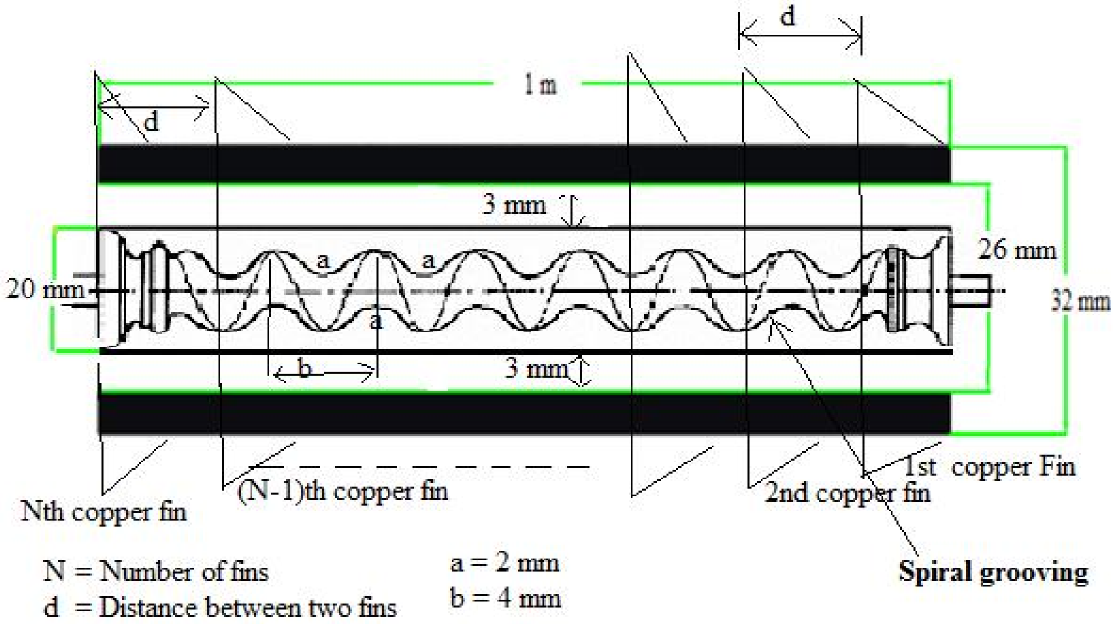

Figure 3:Layout of internal spiral groove concentric tube with rectangular copper fin heat exchanger with different distance.

Figure 4: Physical setup for heat exchanger with spiral grooving with rectangular copper fin.

III RESULTS AND DISCUSSION

This section is dedicated to the result calculated for the proposed setup of eight variations of Air-Cooled Heat Exchanger (ACHE) design with internal grooving; all of them are having variable fin distance. The calculation of various parameters [13,14] starts with the calculation of discharge through the internally grooved tube.

Discharge through the pipe = 0.00025 m3/s

Area of cross sectional through which hot fluid flow = $\pi/4\ (D_o^2 - D_i^2)$ (1)

$$= \pi/4\ (26^2 - 20^2)$$

$$= 216.77\ mm^2$$

Velocity of hot fluid = Q/A = $0.00025/(216.77 \times 10^{-6}) = 1.15$ m/s (2)

A comparative analysis of heat transfer rate for counter to cross flow ACHE is presented in

Table I.

Table I: Heat transfer rate of a counter to cross flow ACHE for proposed setup.

	Distance between fins (mm)	Without fan heat transfer rate (Watt)	With fan heat transfer rate (Watt)
Proposed setup, Internal circular grooving with rectangular fins at different distance(in mm)	5	7833.77	8007.46
	10	4068.13	4084.81
	15	2736.95	2754.69
	20	2161.49	2205.98
	25	1802.89	1809.24
	30	1546.44	1555.39
	35	1336.51	1352.88
	40	1165.74	1172.78

For the different values obtained in the above setup we will now calculate the effectiveness of our proposed heat exchanger.

$$\in = \frac{Q_{actual}}{Q_{max}} = 1\text{-}\ e\left(\frac{e^{-C.(NTU)^{0.78}}-1}{C.(NTU)^{-0.22}}\right) \quad (3)$$

Where C = Heat capacity ratio = $\frac{C_{max}}{C_{min}}$, and NTU is number transfer unit.

The overall fin effectiveness of the proposed setup are 28.11, 14.82, 10.22, 8.07, 6.69, 5.74, 4.93 and 4.39 the distance between two consecutive fins are 5 millimeters, 10 millimeters, 15 millimeters, 20 millimeters, 25 millimeters, 30 millimeters, 35 millimeters and 40 millimeters respectively.A function of capacity ratio (C) and numberoftransferunit (NTU) for the effectiveness of counter to cross flow air cooled heat exchanger can be certainly calculated.

Table II: Calculation table of heat exchanger effectiveness for proposed setup.

Distance between two consecutive fins (in mm)	5	10	15	20	25	30	35	40
Total no of finsx	200	168	68	52	42	35	29	25
∈cross flow ACHE (in percentage)	12.08	6.88	4.84	3.86	3.23	2.77	2.40	2.12

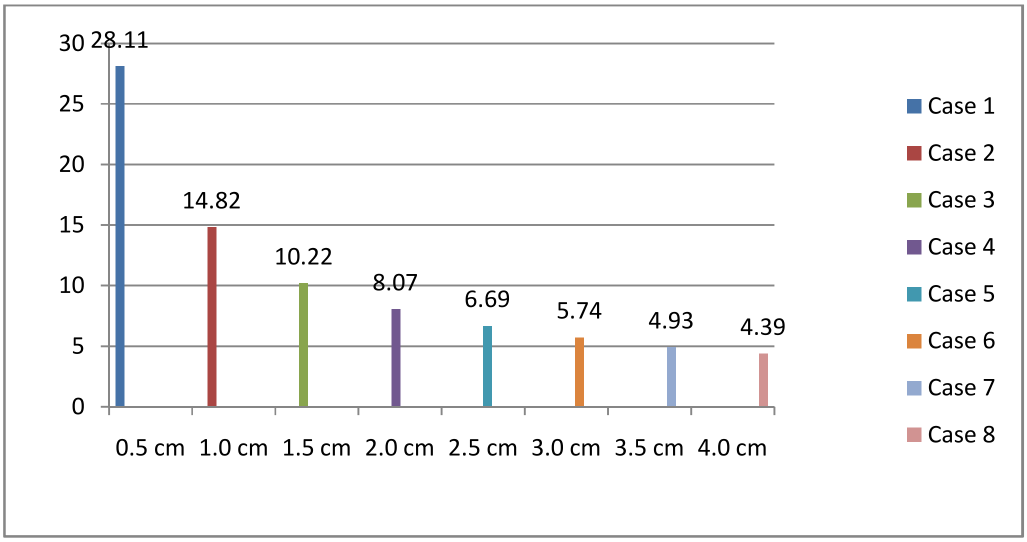

Figure 5.Graph between overall fin effectiveness (y-Axis) and distance between fins (x-Axis).

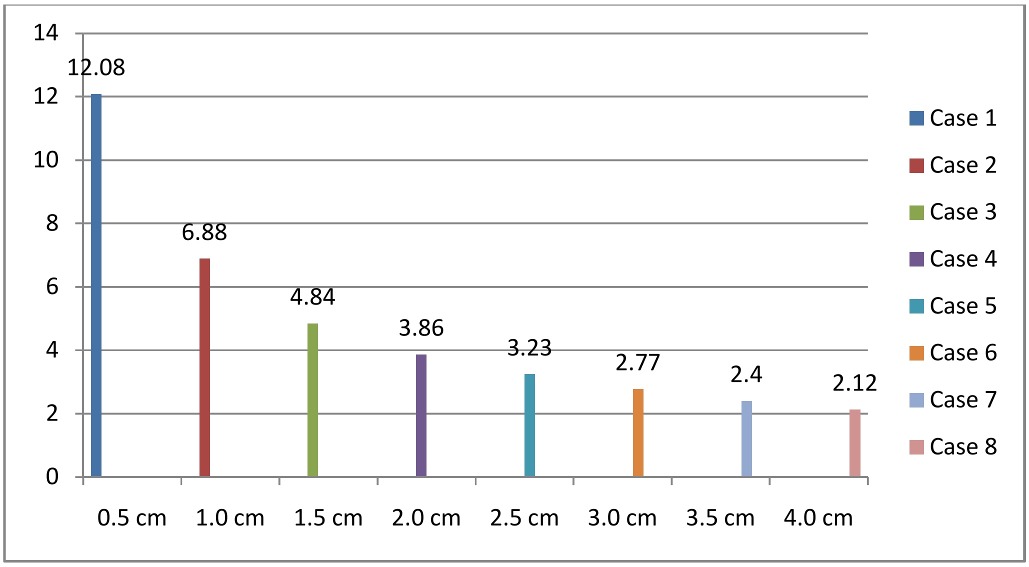

Figure 6.Graph between graph between effectiveness of cross flow ACHE (y-Axis) and distance between fins (x-Axis).

IV CONCLUSION

In this paper, a exhaustive examination is displayed on various spiral grooved concentric tune heat exchanger with copper fins at different fin pitch and variable number of fins. From the result analysis we found that the heat transfer rate is maximum in internal spiral grooving in concentric tube with rectangular copper fins for distance between two consecutive fins are 5 mm, a total of 200 fins are used for the proposed setup. For all proposed design we find that forced convection outperform as compared to natural convection so far is heat transfer rate is concerned in case of forced convection we found that the heat transfer rate is maximum in internal spiral grooving in concentric tube with rectangular copper fins for distance between two consecutive fins are 5 mm as well. We can conclude that the heat exchanger with in internal spiral grooving in concentric tube with rectangular copper fins for distance between two consecutive fins are 5 mm is more desirable from heat transfer rate, efficiency of fins, effeteness of fins and effectiveness of cross flow ACHE point of view.

There is a large scope to modify in this field. We can also work on the size reduction of the proposed heat exchanger designing to obtain optimized performance parameters. Further research can be carried out on different material used for heat exchanger and fins.

References

[1] BayramSahin et al., Optimization of design parameters for heat transfer and friction factor in a heat sink with hollow trapezoidal baffles, Applied Thermal Engineering ,VOL-154, PP: 76–86, 2019.

[2] JieQu et al., Experimental investigation on thermal performance of phase change material coupled with three-dimensional oscillating heat pipe (PCM/3DOHP) for thermal management application, International Journal ofheat and Mass Transfer, VOL-129, PP: 773–782, 2019.

[3] Hassan JafariMosleh et al., Experimental and numerical investigation of using pulsating heat pipes instea of fins in air-cooled heat exchangers, Energy Conversion and Management, VOL-181, PP:653–662 , 2019.

[4] Jian Wang et al., Experimental investigation of heat transfer and flow characteristics in finned copper foam heat sinks subjected to jet impingement cooling, Applied Energy, VOL-241 ,PP: 433–443, 2019.

[5] De-Shau Huang et al, Design of fins with a grooved heat pipe for dissipation of heat from high powered automotive LED headlights, Energy Conversion and Management ,VOL-180 ,PP: 550–558 , 2019.

[6] Hai Wang et al. , Heat transfer performance of a novel tubular oscillating heat pipe with sintered copper particles inside flat-plate evaporator and high-power LED heat sink application, Energy Conversion and Management, VOL-189 ,PP:215–222, 2019.

[7] DemisPandelidis et al., Performance comparison between counter- and cross-flow indirect evaporative coolers for heat recovery in air conditioning systems in the presence of condensation in the product air channels, International Journal of Heat and Mass Transfer, VOL-130, PP:757–777 , 2019.

[8] Lei Wang et al., Optimization of the counter-flow heat and mass exchanger for M-Cycle indirect evaporative cooling assisted with entropy analysis, Energy, VOL-171 ,PP:1206e1216 , 2019.

[9] Anna Pacak et al. , Analysis of power demand calculation for freeze prevention methods of counter flow heat exchangers used in energy recovery from exhaust air, International Journal of Heat and Mass Transfer VOL-133 ,PP:842–860 , 2019.

[10] Ali Pakari et al., Regression models for performance prediction of counter flow dew point evaporative cooling systems, Energy Conversion and Management ,VOL-185 ,PP:562–573, 2019.

[11] Xia Song et al. , Analysis of the temperatures of heating and cooling sources and the air states in liquid desiccant dehumidification systems regenerated by return air , Energy, VOL-168 ,PP: 651e661 , 2019.

[12] MircoRampazzo et al. , A static moving boundary modelling approach for simulation of indirect evaporative free cooling systems, Applied Energy ,VOL-250, PP:1719–1728, 2019.

[13] S. Jamshed et al.,“ Numerical flow analysis and heat transfer in smooth and grooved tubes”, ISSN 1743-3533 (on-line) WIT Transactions on Engineering Sciences, Vol-105, © 2016 WIT Press doi:10.2495/AFM16014.

[14] Fei-Long Wang et al., “Heat transfer and fouling performance of finned tube heat exchangers: Experimentation via on line monitoring”, www.elsevier.com/locate/fuel, Vol-236, pp: 949-959, January2019.