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Experimental Study for Counter to Cross Flow Air Cooled Heat Exchanger in Concentric Tube using Rectangular Copper Fins Spacing 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 spiral grooving, all of them are having variable number of rectangular 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 0.5 cm, 1.0 cm, 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm, 3.5 cm and 4.0 cm 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 0.5 cm, 1.0 cm, 1.5cm, 2.0 cm, 2.5 cm, 3.0 cm, 3.5 cm and 4.0 cm respectively.

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

I. INTRODUCTION

A heat exchanger is a device that is used to transfer thermal energy between different fluids [1,2], between solid particulates and a fluid or even between a solid surface and a fluid, at different operating temperatures and in an environment of thermal contact. In heat exchangers, there are typically no external heat and work exchanges. Classic applications involve heating or cooling of a fluid stream for single or multi-component fluid streams. In other applications, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distill, concentrate, crystallize, or control a process fluid. In a few heat exchangers, the fluids exchanging heat are in direct contact. In most heat exchangers, heat transfer between fluids takes place through a separating wall or into and out of a wall in a transient manner. In many heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix or leak. Such exchangers [3,4] are referred to as direct transfer type, or simply recuperators. In contrast, exchangers in which there is intermittent heat exchange between the hot and cold fluids via thermal energy storage and release through the exchanger surface or matrix are referred to as indirect transfer type, or simply regenerators. Such exchangers usually have fluid leakage from one fluid stream to the other, due to pressure differences and matrix rotation or valve switching. Common examples of heat exchangers [5,6] are shell-and tube exchangers, automobile radiators, condensers, evaporators, air preheaters, and cooling towers. 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 Surface Compactness
a. Gas-to-Fluid Exchangers
b. Liquid-to-Liquid and Phase-Change Exchangers
(4) Classification Based on Construction Features
a. Tubular Heat Exchangers
b. Plate-Type Heat Exchangers
c. Extended Surface Heat Exchangers
d. Regenerators
(5) Classification Based on Flow Arrangements
a. Single-Pass Exchangers
b. Multipass Exchangers
(6) Classification Based on to Heat Transfer Mechanisms

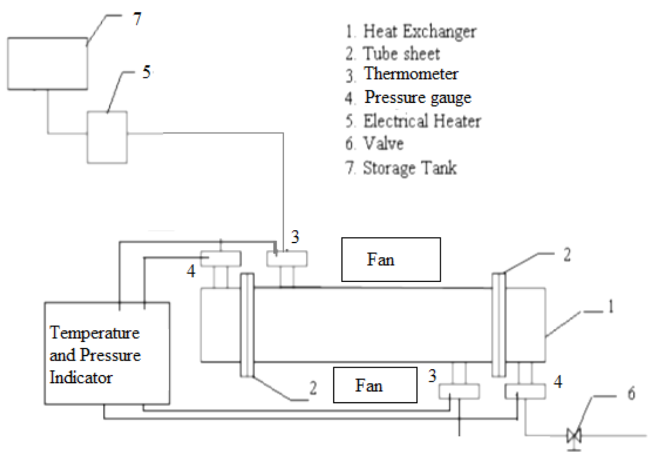

Figure 1. Schematic diagram of basic experimental set-up.

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 spiral grooving, rectangular copper fins 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 rate of heat exchanger. In the proposed work we are taking 8 variation of fin pitch viz. 0.5 cm, 1.0 cm, 1.5cm, 2 cm, 2.5 cm, 3.0 cm, 3.5 cm and 4 cm respectively with varying number of fins (200 to 25).

The rest of the paper is organized 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 2 mm and pitch length of 4 mm on aluminum material [12,13] and variable rectangular 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 in fig 3. The overall length of the proposed tube is again 1 meter standard dimension.

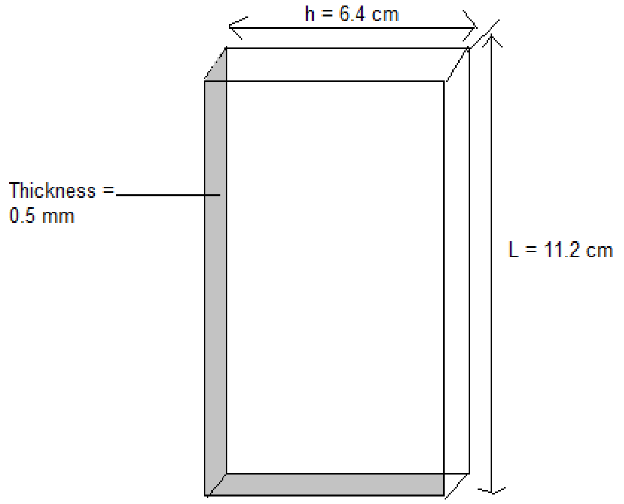

Figure 2 : Layout of rectangular copper fin of proposed heat exchanger.

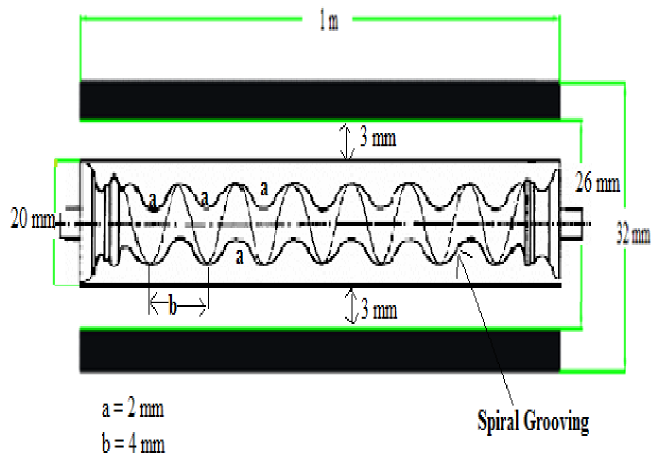

Figure 3 : Layout of concentric tube heat exchanger with internal spiral grooving.

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 0.5 cm, 1.0 cm, 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm, 3.5 cm and 4.0 cm 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. 4, 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.

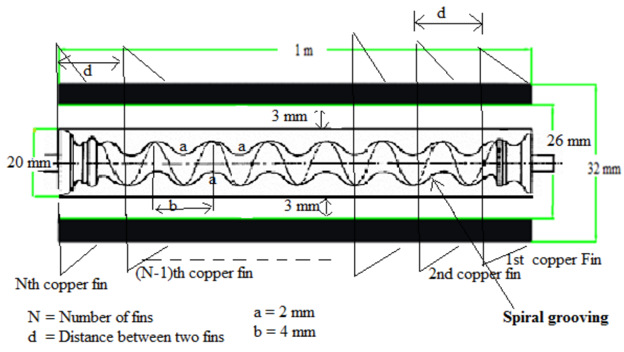

Figure 4 : Layout of internal spiral groove concentric tube with rectangular copper fin heat exchanger with different distance.

Figure 5 : 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 spiral 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 spiral grooved tube.

Discharge through the pipe = 0.00025 m^3/s

Area of cross sectional through which hot fluid flow = $\pi/4\ (D_o^2 - D_i^2) = \pi/4\ (26^2 - 20^2)$

$$= 216.77\ mm^2 \quad (1)$$

Velocity of hot fluid = Q/A (2)

$= 0.00025/(216.77 \times 10^{-6}) = 1.15$ m/s

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.

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

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 0.5 cm, 1.0 cm, 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm, 3.5 cm and 4.0 cm respectively. A function of capacity ratio (C) and number of transfer unit (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 fins	200	102	68	52	42	35	29	25
∈ of cross flow ACHE (in percentage)	12.08	6.88	4.84	3.86	3.23	2.77	2.40	2.12

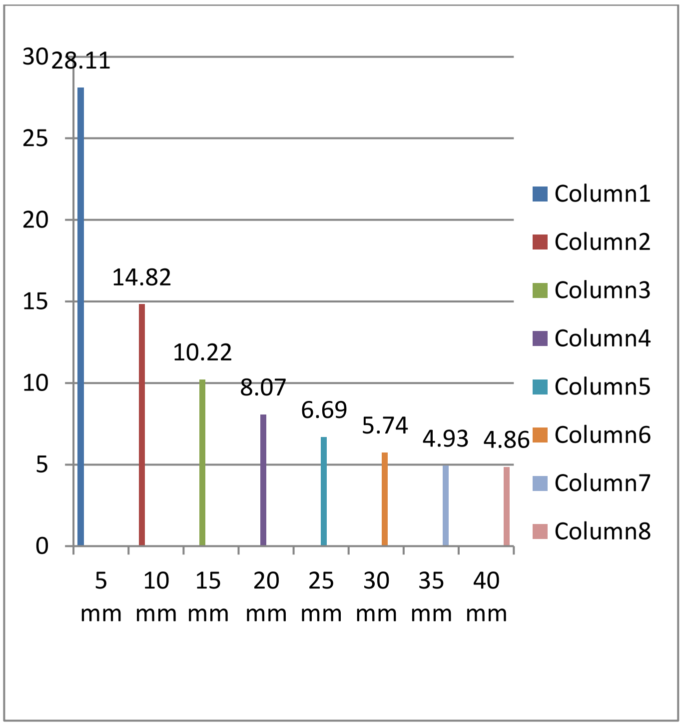

Figure 6. Graph between overall fin effectiveness (y-Axis) and distance between fins (x-Axis).

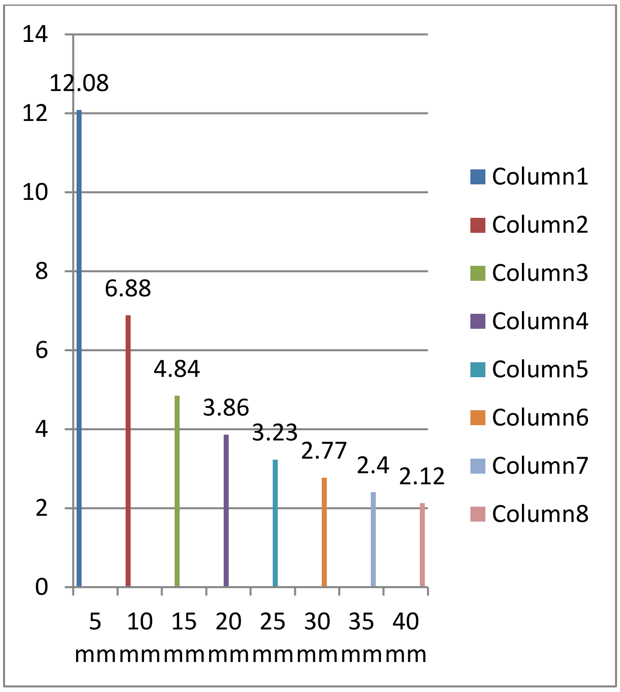

Figure 7. Graph between graph between effectiveness of cross flow ACHE (y-Axis) and distance between fins (x-Axis).

IV. CONCLUSION

In this paper, a exhaustive examination is displayed on various spiral grooved concentric tune heat exchanger with rectangular 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.

V. 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]. Demis Pandelidis 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.

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