Experimental Study of Counter to Cross Flow Air-Cooled Heat Exchanger with Variable Fins Spacing Using Internal Circular Grooving

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Abstract:

In this manuscript we have presented seven variation of Air-Cooled Heat Exchanger (ACHE) design with internal grooving, all of them are having variable number of aluminum 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 7062.95 watt, 3969.98 watt, 2724.15 watt, 2149.25 watt, 1785.03 watt, 1533.43 watt, and 1325.34 watt in natural convection (without fan) for 0.5 cm, 1 cm, 1.5 cm, 2 cm, 2.5 cm, 3 cm and 3.5 cm respectively. Then again, value of rate of heat transfer in forced convection (with fan) are 7100.40 watt, 3995.34 watt, 2740.54 watt, 2162.30 watt, 1797.63 watt, 1540.00 watt, and 1331.60 watt for 0.5 cm, 1 cm, 1.5cm, 2 cm, 2.5 cm, 3 cm and 3.5 mm respectively.

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

I. INTRODUCTION

Nowadays, Heat exchanger is one of the most widely used devices including different industries, plants like petrochemical plants, petroleum refineries and many more and automobiles. Heat exchangers are used to transfer heat between two process streams mostly. It can be easily understood that utilization of any process which consist of evaporation, condensation, heating, boiling or cooling will definitely require a heat exchanger for all of these purposes [12,13,14]. The estimation of efficiency & performance of heat exchangers can be done through the total heat transferred by utilizing the least area of heat transfer and pressure drop. Overall calculation of heat transfer coefficient can help one understand the better presentation of their efficiency. A good design can be referred to heat exchangers which have least possible area and pressure drop to accomplish the heat transfer requirements. We know it very well that it is an industrial challenge to improve the effectiveness of heat exchangers [2] and heat transfer [1, 4]. In thermal power plants, Chemical refineries, ORC Plant, Oil & Gas, Steel Industry and in many other applications, Air-cooled heat exchangers [3,4] are widely used. Nowadays, heat exchangers are obtainable in many configurations. Classifications of heat exchangers [2,5] depends upon their application, process fluids, and mode of heat transfer and flow.

The most standard method to improve the heat transfer rate is the use of turbulence promoters or roughness components, like groove, wires, rib or wounded on the face of it [6,7]. To get better performance of heat exchangers a general method can be used which is by putting up regular interval disturbance promoters along with the stream wise manner. Because of flow mixing and periodic disruptions of thermal boundary layers, arrangement of the channels may take to the increment of the heat transfer, but regularly causes an increase of pressure drop [7]. More competent heat transfer can be supported by Grooved tubes than smooth tubes [8,9]. The basic setup for heat exchanger [10,11] under test is shown in fig 1.

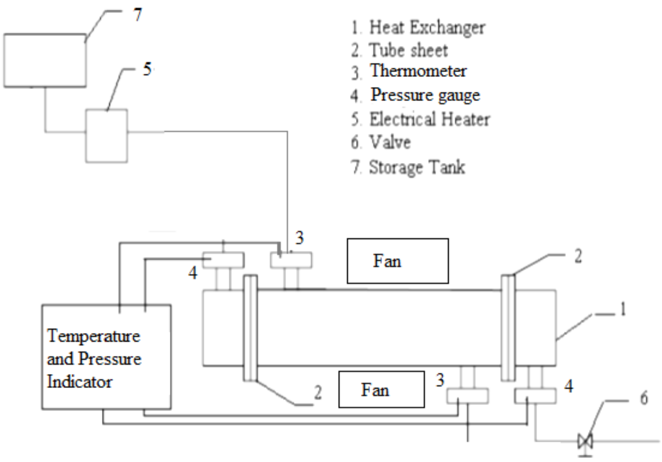

Figure 1.Schematic diagram of basic experimental set-up.

The rest of the paper is organized in four sections. Section II is used to describe all of the proposed design with its dimension. Section III presents the various performance parameters 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 seven variations is fin distance with rectangular fin of thickness of 0.5 mm, height = 6.4 cm and characteristic length = 11.2 cm, calculated using standard formulas is shown in fig. 2

Here we use internal circular grooving with radius of 3 mm and pitch length of 6 mm on aluminum material [12,13] 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.

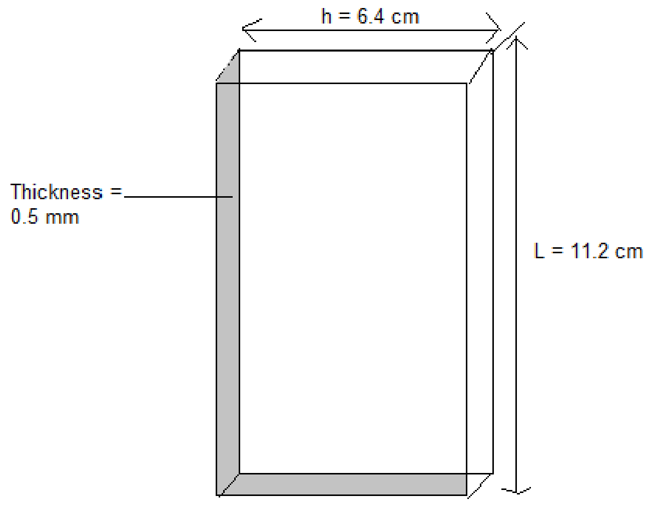

Figure 2: Layout of rectangular Fin of proposed heat exchanger.

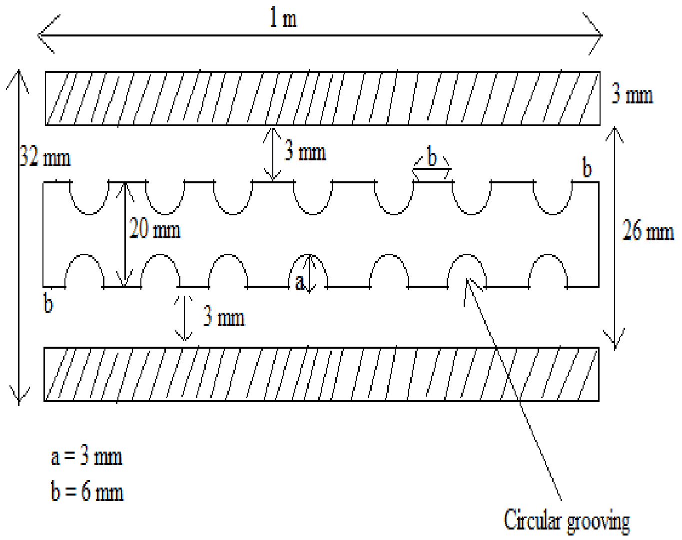

Figure 3: Layout of heat exchanger with internal grooving with rectangular fin.

We are also changing the difference between fins in order to get the most optimized design in terms of performance as well as cost, for that we are taking seven 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 cm, 1.5 cm, 2 cm, 2.5 cm, 3.0 cm and 3.5 cm in 7 proposed setup for the ACHE with 200, 102, 68, 52, 42, 35 and 29 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 consecutive fins.

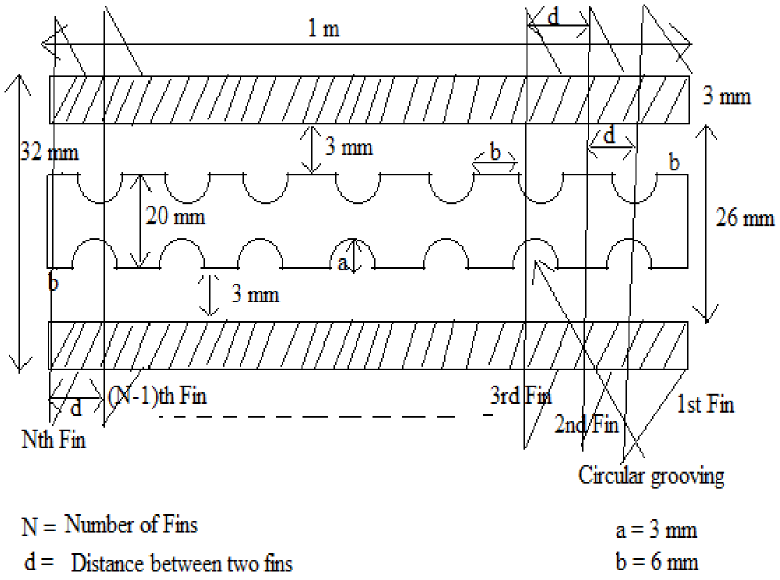

Figure 4: Layout of internal groove rectangular fin heat exchanger with different distance.

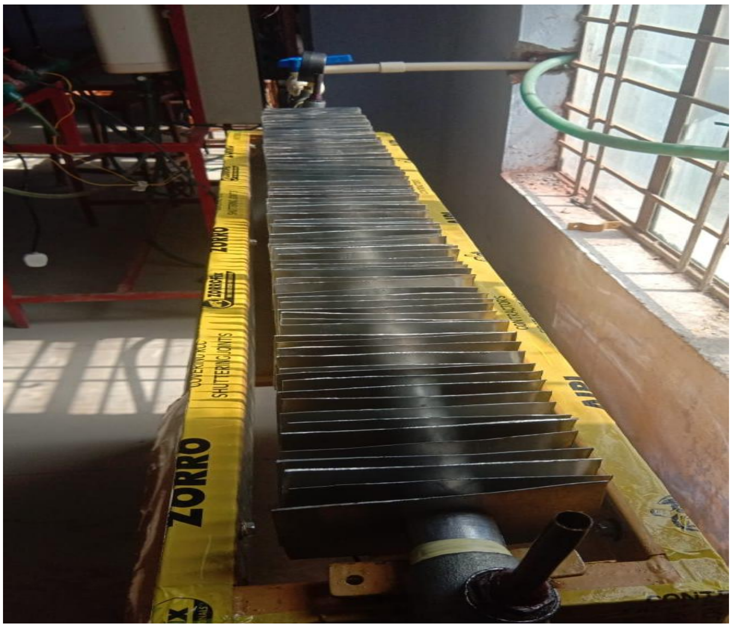

Figure 5: Physical setup for heat exchanger with internal grooving with rectangular fin.

III. RESULTS AND DISCUSSIONS

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

Discharge through the pipe = 0.000384 m3/s
Area of cross sectional through which hot fluid flow = π/4 (Do2 – Di2) (1)
= π/4 (262 - 202) = 216.77 mm2
Velocity of hot fluid = ρ/A = 0.000384/(216.77 × 10-6) = 1.77 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	7062.95	7100.40
	10	3969.78	3995.30
	15	2724.15	2740.54
	20	2149.25	2162.30
	25	1785.03	1797.63
	30	1533.43	1540.00
	35	1325.34	1331.60

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 27.59, 14.56, 10.04, 7.91, 6.58, 5.56, and 4.86 at the distance between two consecutive fins are are0.5 cm, 1 cm, 1.5 cm, 2 cm, 2.5 cm, 3 cm, 3.5 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
NTU	0.142	0.075	0.052	0.041	0.034	0.029	0.025
$C = C_{min}/C_{max}$	0.63	0.63	0.63	0.63	0.63	0.63	0.63
cross flow ACHE (in percentage)	12.43	6.95	4.92	3.92	3.27	2.80	2.43

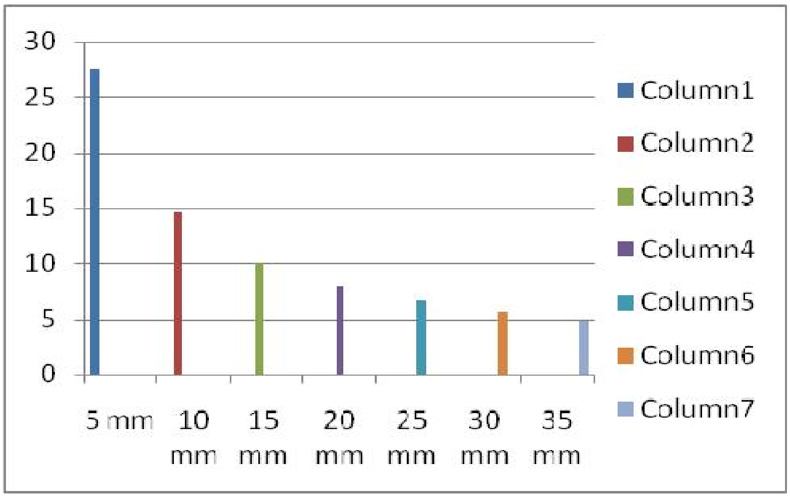

Figure 6.Graph between overall fin effectiveness (y-Axis) and distance between fins (x-Axis).

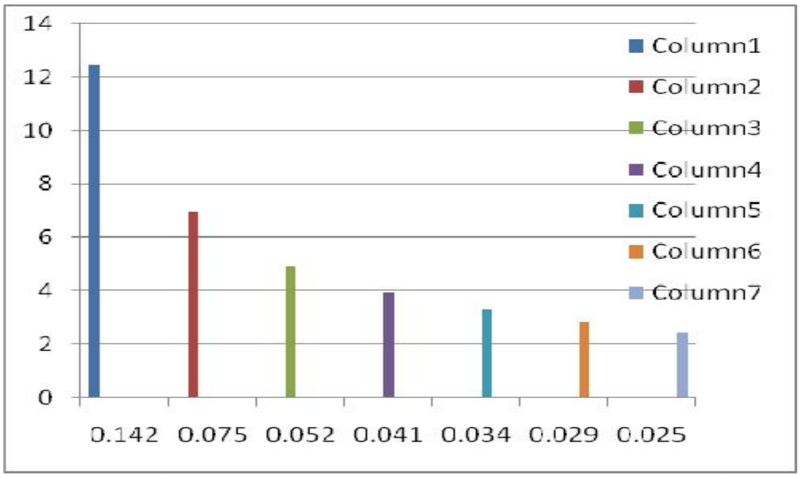

Figure 7.Graph between graph between effectiveness of cross flow ACHE (y-Axis) and NTU (x-Axis).

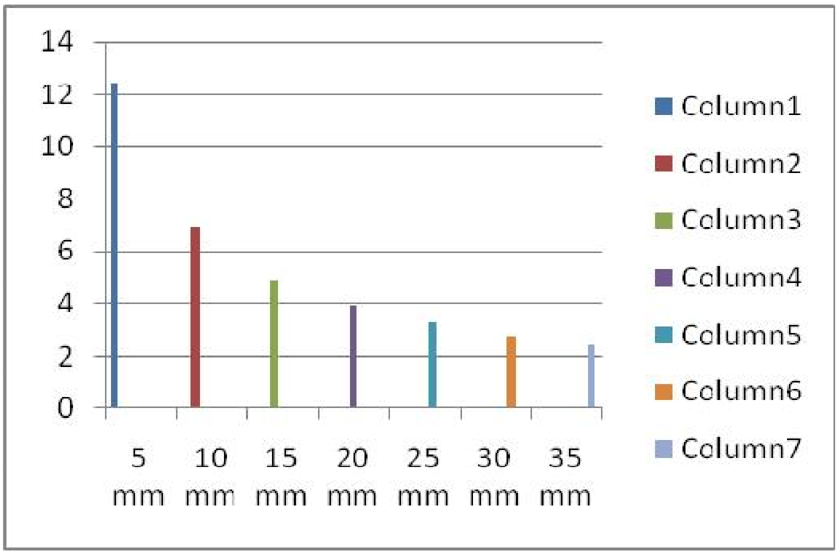

Figure 8.Graph between graph between effectiveness of cross flow ACHE (y-Axis) and distance between fins (x-Axis).

IV. CONCLUSION

On concluding the result of this manuscript we can find that the heat transfer rate is maximum in internal circular grooving with rectangular fins at the distance between two fin is 5 mm. The heat exchanger effectiveness is also higher than other arrangement. We can conclude that the heat exchanger with fins which is placed at 5 mm is more desirable from heat transfer point of view. But on the basis of economical point of view, the heat exchanger with rectangular fins which is placed 35 mm is more desirable because the number of fins required is very less compared to other arrangement. The overall better performance i.e more appropriates of heat transfer as well economical point of view of heat exchanger is the exchanger with rectangular fins which is placed at 10 mm, because in this case less number of fins are required and better heat transfer compared to others.

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