Experimental Analysis of Heat Transfer Characteristics in a Square Duct with Perforated Internal Fins

Saravana Sathiya Prabhahar R, Arjun Kumar M, Gowsik Kumaran P, Arumugesh K S

Abstract--- ***Developing high-efficiency heat exchanging equipment such as heat exchangers and solar air heaters is an effective way to conserve energy. In order to achieve this objective, fins can be introduced on the internal surface of heat exchangers. For higher efficiency the surface area of contact of these fins has to be increased. So, Perforations like circular holes are also introduced in these internal fins to get higher efficiency. Different arrangement configurations like Parallel oriented (P type) and collinearly oriented (V type) with different materials such as Aluminium and Brass with and without perforations different velocities are investigated and found to have different heat transfer characteristics. From this study the optimum orientation, material and profile of the fin is identified for better heat transfer characteristics.***

Keywords: P type and V type Ribs, Internal fin, heat transfer, square duct

1. INTRODUCTION

Energy conservation is a requisite now-a-days and that has led the way to design and develop more efficient ways to increase the heat transfer characteristics. Removal of excessive heat from a component is very important in order to ensure the safeness of the system from overheating. The fluid flowing in a system has to be either Laminar or Turbulent. In Laminar the flow is very smooth, where the flow happens layer by layer. Also, in laminar flow, around the channel wall, it develops an insulating blanket which restricts the heat transfer. On the other hand, the fluid does not flow in a smooth layer in a turbulent flow. Thus, in turbulent flow the fluid is more agitated than in laminar. Agitated fluid is more likely to transfer heat than a laminar. Some kind of blocks in flow tends to increase the drop-in pressure which increases the viscous effects and introduces the turbulence in the flow. Therefore, some kind of inserts can be introduced in the passage of flow in order to enlarge the heat transfer area and also changes the flow to turbulent by which, the heat transfer coefficient increases ultimately.

Heat transfer area is also an important factor for heat transfer through fins. In order to increase this heat transfer area, perforations can be introduced in these fins. Clearly the fins with perforations has superior heat transfer than that of the one with no perforations [1]. Also, the configurations of these fins can be changed by arranging them in different manner [2]. Here, the fins are arranged in P-type and V-type [3]. In P-type arrangement the fins are arranged in a parallel manner and the spacing is even between each fin. In V-type arrangements the fins are arranged in a V shaped manner and in this arrangement also, the fins are equally spaced. In this paper the heat transfer characteristics is investigated for fins made of Aluminium and Brass, both with and without perforations in it and both arranged in P-type and V-type in both cases. When double-fin cases are considered, reducing the angle from 150° to 45° results in considerable difference in heat transfer performance [4]. More reduction in the angle increases the total melting time. By varying fin spacing, orientation the maximum transfer characteristics is achieved [5].

2. MATERIALS AND METHODS

2.1. Materials

The duct is made of four aluminium plates enclosed to form a channel where the fluid flows. The atmospheric air is taken as the fluid. The duct has square cross section. The outer layer is made up of Balsa wood. Glass wool is used for insulation. It is placed on all four sides inside the duct. Strip heaters are placed on the top and bottom face of the duct. Then the aluminium plates are placed inside. The fins are attached on the top and bottom sides. The effect of variability in different parameters on temperature distribution in fin is studied in detailed [6]. Further, by using nanofluid as a working fluid we can enhance the performance of microchannel with longitudinal fins [7]. But we chose air as a working fluid.

The properties of air at 30°C are given in the Table No.1 given below.

PROPERTIES	VALUE
Density [kg/m^3]	1.16
Absolute Viscosity [N s/m^2]	18.63x10^{-6}
Kinematic Viscosity [m /s^2]	16x10^{-6}
Prandtl Number	0.701
Specific Heat [J/kg K]	1005
Thermal Conductivity [W/m K]	0.02675

Table No.1 Properties of air

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2.1.1Balsa wood

The square shaped duct is made up of balsa wood. The balsa wood was chosen because of its thermal and mechanical properties. It is also cheap and has good insulating properties. It also has good strength.

2.1.2 Glass Wool

Glass wool is a commonly used thermal insulation material. It is made up of fibre glass. Its texture is similar to that of the wool. It is available in various forms like rolls or slabs. Due to small air pocket present in the glass wool, it has high thermal insulation properties. It is also cheap and readily available. Hence glass wool is used as insulation in the duct.

2.1.3 Aluminium

Aluminium is used as fin material due to its light weight, good corrosion resistant and good thermal conductivity. Also, it is ductile in nature and possesses high strength to weight ratio.

2.1.4 Brass:

Brass is an alloy of copper and zinc. Brass is chosen as fin material because it is easy to machine, good thermal conductivity and cheap. Also, it has sufficient strength and is readily available.

2.2 Methods

Figure 1.a and 1.b shows the experimental setup used. The outer cover is made up of wood, followed by a layer of Glass Wool, strip heater, followed by four plates and then the internal fins. Figure 2 shows the model of the setup.

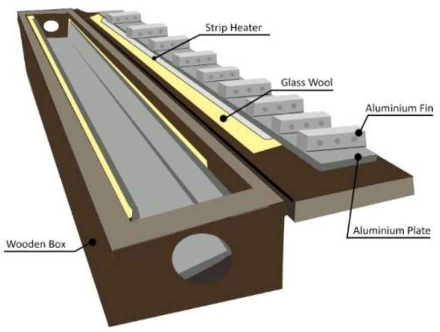

Fig 1. a Experimental Setup(Al)

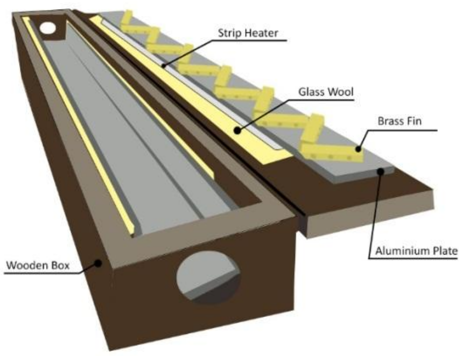

Fig 1. b Experimental Setup (Brass)

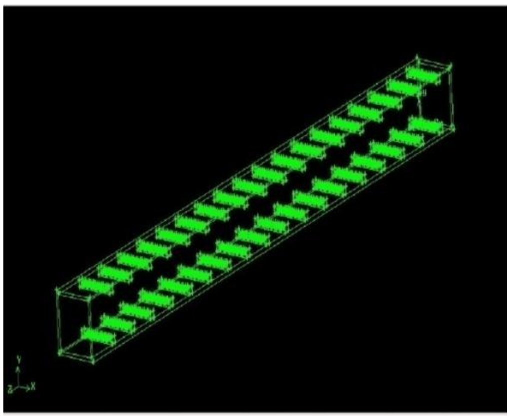

Fig 2. Model of P type arrangement

The experiment was conducted by keeping the fins in two different configurations. Also, two types of fins were used, Fins with holes and Fins without holes. Experiments conducted with aluminium and brass as fin material and the results are tabulated in the Table No.2 and Table No.3.

Initially the heaters are turned on to heat the fins. Then the compressor is turned on. The velocity of air is changed by adjusting the valve provided at the outlet of the compressor. The velocity of the air at the outlet of the compressor is measured with the help of anemometer. The setup is left undisturbed for 20 minutes. When the setup reaches steady state, the temperatures are noted from the temperature indicators. The experiments are repeated for different trials to ensure error free readings and are tabulated. This could be used for cooling also by incorporating the system to the cooling system instead of heater [8].

The Nusselt number is calculated using the following formula

$Nu_x=\frac{h*D_h}{K}$, where hx= $\frac{q}{(Tw-Tf)}$here,

hx = heat transfer coefficient W/m^2K, q = heat flux = $1020W/m^2$, T_w = wall temperature in °c

T_f = fluid temperature in °c Nu_x = local Nusselt number

D_h = hydraulic diameter = 0.05 m, k = thermal conductivity W/m K

Material: Aluminium

Sl.No	CONFIGURATION	TYPE	RENOYLD'S NUMBER (Re)	NUSSELT NUMBER (Nu)
1	P-TYPE	With Perforation	13221.60	120.64
2			11467.88	96.94
3			9723.95	69.49
4			8043.06	53.69
5		Without Perforation	13001.57	91.56
6			11281.58	76.97
7			9570.79	58.36
8			7920.75	46.64
9	V-TYPE	With Perforation	13251.50	130.83
10			11493.19	103.50
11			9744.74	72.87
12			8059.66	55.74

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13		Without Perforation	13132.70	111.68
14			11392.63	90.96
15			9662.10	66.27
16			7993.69	51.69

Material: Brass

Sl. No	CONFIGURATION	TYPE	RENOYLD'S NUMBER (Re)	NUSSELT NUMBER (Nu)
1	P-TYPE	With Perforation	13132.70	104.24
2			11392.63	85.91
3			9662.10	63.51
4			7993.69	49.97
5		Without Perforation	12944.12	81.75
6			11232.92	69.83
7			9530.75	54.09
8			7888.75	43.81
9	V-TYPE	With Perforation	13191.83	120.52
10			11442.69	96.84
11			9703.24	69.42
12			8026.54	53.64
13		Without Perforation	13001.57	91.56
14			11281.58	76.97
15			9570.79	58.36
16			7920.75	46.64

3. RESULTS AND DISCUSSIONS

The readings are plotted on the graph. Fig 3 compares the heat transfer of aluminium and that of brass. Fig 4 compares the heat transfer of P-type and V-type configuration as well as the fins with and without perforations when aluminium is used. Fig 5 compares the heat transfer of P-type and V-type configuration as well as the fins with and without perforations when brass is used. Fig 6 compares the average heat transfer by P-type and V-type configuration. Fig 7 compares the average heat transfer by fins with and without holes. By the configuration PCM could have better heat transfer characteristics [9].

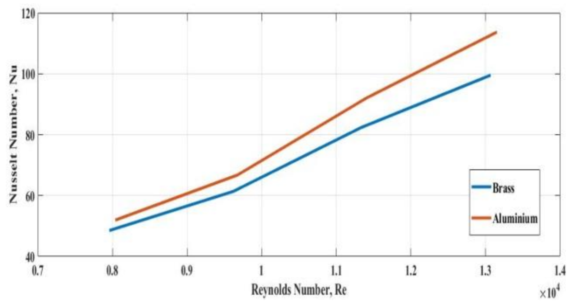

Fig 3. Nusselt number Vs Reynold's number comparing Aluminium and Brass

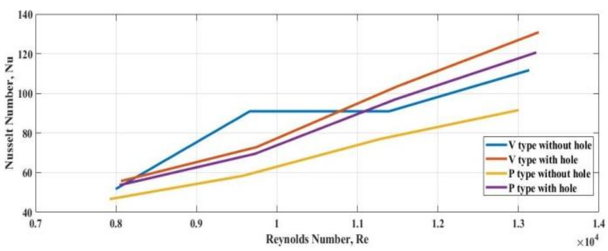

Fig 4. Nusselt number Vs Reynold's number for aluminium for different configurations

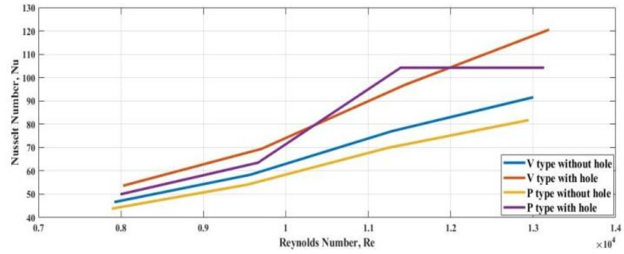

Fig 5. Nusselt number Vs Reynold's number for Brass for different configurations

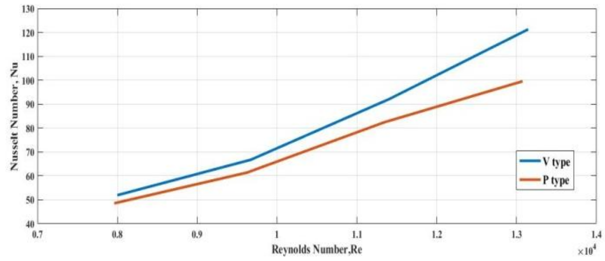

Fig 6. Nusselt number Vs Reynold's number comparing P-type and V-type configurations

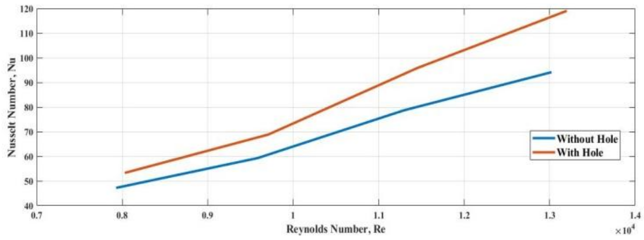

Fig 7. Nusselt number Vs Reynold's number comparing fins with hole and fins without holes

From the above graphs (Fig 3 to Fig 7) it is observed that as the velocity increases which leads to the increase of Reynolds number the Nusselt number also varies. Initially when the velocity of air is maximum, the Nusselt number which in turn the heat transfer is efficient. As the velocity is reduced gradually, the heat transfer also reduces gradually.

4. CONCLUSION:

In this work, the enhancements of heat transfer by using perforated internal fins were studied. The variation of convective heat transfer coefficient from velocity 3 m/s to 4.5 m/s has been studied experimentally. It is observed that Aluminium fins offer better heat transfer than Brass fins. Also, V-type configuration has higher heat transfer rate than P-type. Fins with perforations (holes) have higher surface area than fins without holes, thus the heat transfer rate is better in fin with holes. Thus, by using aluminium fins with circular holes in V-type configuration enhances the heat transfer rate.

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