Experimental Investigation of Heat Transfer by Natural Convection with Alternatively Arranged Horizontal Rectangular Staggered Fins

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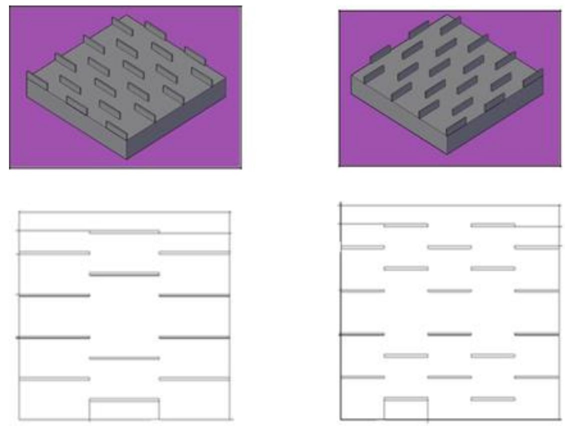
Abstract— Fins are used for to enhance the heat transfer rate in many devices as they can enhance the heat transfer to particular environment. The application of fins enables the overall increase in the efficiency of device. As today emphasis is given on increase in effectiveness and efficiency of the heat exchanging devices now days use of different types fins becoming more and more popular in heat exchanging devices like heat exchangers, engines, radiators etc. the aim of this paper is to provide a review on use of horizontal rectangular staggered fins in natural convection to increase heat transfer rate and convective heat transfer coefficient.

Key words: Heat transfer enhancement, Natural convection, Fins

I. Introduction

Fins are extended surfaces which are used to improve the overall heat transfer rate when it is limited by low rate between a solid surface and surrounding fluids. Due to the high demand for lightweight, compact, and economical fins, the optimization of the fin size of great importance. Therefore, fins must be designed to achieve maximum heat removal with minimum material expenditure, taken into account, and also with the ease of manufacturing the fin shape. A large number of studies have been conducted on optimizing fin shapes. Other studies have introduced shape modifications by cutting some materials from fins to make cavities, holes, slot, groove, notches or the channels through the fin body to increase heat transfer area and the heat transfer coefficient[3].

Enhancement of natural convection heat transfer is necessary because of the continuous increase of power consumption rate of equipment. The heat can be removed effectively if the fluid flow and the resulting flow pattern are capable of removing the heat efficiently. The heat dissipation from fins under natural convection condition depends on the geometry and orientation of finned surface. Whenever the available surface of fins is found inadequate to transfer the required quantity of heat with the available temperature drop, staggered fin surfaces are used [5]. The heat transfer through staggered fins is greater than the normal fin pattern.



a) 20% staggering b) 40% staggering

Fig. 1: Horizontal staggered fin with 20% & 40%

II. Literature review

As the fins are very important parts to enhance the heat dissipation rate so it is necessary to study by considering various parameters it may be theoretical or by experiments,

Baskaya et al. [1] works by using aluminum material for his parametric study They studied each of the variables of fin spacing, height, and length and temperature difference produces an effect on the overall heat transfer rate They investigated the effects of a wide range of geometrical parameters like fin spacing, fin height, fin length and temperature difference between fin and surroundings; to the heat transfer from horizontal fin arrays. However, no clear conclusions were drawn due to the various parameters involved. Finally they concluded that, it is not possible to obtain optimum performance in terms of overall heat

Tanda et al.[5] studied the thermal field and the heat transfer characteristics of a system consisting of two staggered vertical plates cooled by air in free convection were experimentally studied. The parameters investigated included the inter plate spacing, the magnitude of the vertical stagger, and the Rayleigh number based on the overall convective heat flux from each plate. The experiments were performed in air. The schlieren optical technique was employed to obtain the thermal field around the plates and the local heat transfer coefficients along the vertical sides of plates.

Staggering was found to markedly affect the local heat transfer characteristics of the facing sides of the plates when the inter plate distance was relatively small. In general, the Nusselt number averaged on the inner face of the lower plate was enhanced (up to over 40%) & compared with that for the case of the staggered plate channel. Conversely the mean Nusselt number on the facing side of the upper plate was reduced up to 15%.

Starner et al.[6] studied the Free-Convection Heat Transfer from Rectangular staggered-Fin Arrays and average heat-transfer coefficients are presented for four fin arrays positioned with the base vertical, 45 degrees, and horizontal while dissipating the heat to room air. The fins were analyzed as constant-temperature surfaces since the lowest fin efficiency encountered was greater than 98 %.

It was found that coefficients for the vertical arrays fell about 10 to 30 percent below those of similarly spaced parallel plates. The 45-degree arrays yielded results from 5 to 20 percent below to those of vertical plates. Two flow patterns were investigated for the horizontal arrays, and it was found that the coefficients could be reduced sharply by preventing a three-dimensional flow.

L.Dialameh et al. [7] performed a numerical study to predict the natural convection from an array of aluminum horizontal rectangular thick fins of 3 mm < t < 7 mm with short lengths (L=50 mm) attached on a horizontal base plate. The three-dimensional elliptic governing equations of laminar flow and heat transfer were solved using finite volume scheme. For 128 fin geometries, typical results have been compared with the available experimental data from the literature and good accuracy were observed. Based on the verified model, fluid flow and thermal structure around various fins were illustrated and two types of flow patterns in the channel of the fin arrays were observed. Effect of various fin geometries and temperature differences on the convection heat transfer from the array was determined for Rayleigh numbers based on fin spacing of 192–6784 and applied correlations are developed to predict Nusselt numbers with corresponding non-dimensional parameters.

A. *Problem Statement:*

Experimental Investigation of Natural Convection Heat Transfer with horizontal Rectangular Staggered Fins

B. *Objectives:*

1) To find the heat transfer enhancement due to Staggered Fins
2) To find the performance of heat transfer due to Staggered Fins

III. Experimental Setup

Enhancement of heat transfer under natural convection conditions can be achieved by attaching the fins to the base plate. The base plate will be kept in the perforation made inside the siporex brick. . From the literature survey, it is found that very few investigators have worked on the problems related to this type of arrangement. Hence, it is decided to carry out an experimental work to find the enhancement in heat transfer with the use of staggered fin arrangement. Staggering, usually refers to cutting some fin area and attaching that piece of fin to the next fin array line. The major point of discussion will be to find the best possible staggered arrangement of Fins on the Base Plate.

A. *Requirements of Experimental Setup:*

The major requirement of the experimental setup is the fin and fin array. To ascertain the natural convection conditions, an enclosure is also required. To measure the temperature at various points, thermocouples are required. To indicate the temperatures and heater input values, Instrumentation equipment is needed. To heat the base plate, the heaters are to be provided.

Instrument used in experiments with specification.
Heat input -50w to150w
Height of each fin-30mm
No of fins-4 to16
Ammeter measuring range-0 to 40A
Voltmeter measuring range-2v to20v.
Dimmerstst-rated for 240v ac 50Hz single phase

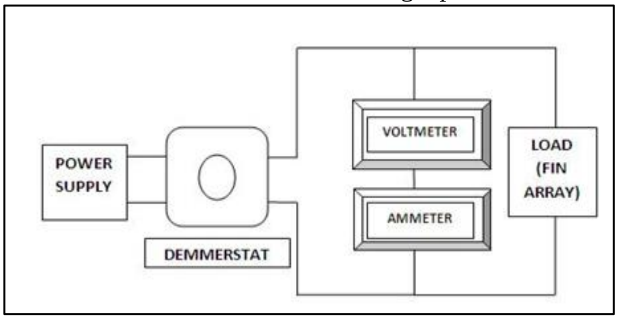


Fig. 1: Experimental Setup Diagram

IV. Experimentation

The actual experimentation carried out is indicated in this chapter. The experimental procedure to be carried out is also given in detail. At times, the experiments were repeated to check the repeatability of the readings under similar conditions. The wattmeter, temperature indicator and thermocouples were calibrated prior to their use during the present experimentation. All the readings were recorded under steady state conditions. Most of the experiments are conducted during early hours of the day, so that there is no much effect of changes in ambient temperature. Normally, it took 3 to 4 hours to reach steady state.

A. *Range of Experimental Work*

The following arrangements are used for the experimentation work:

1) Plain Base Plate
2) Base Plate with Horizontal Fins
3) Base plate with Fins with 33% Staggering
4) Base plate with Fins with 40% Staggering
5) Base plate with Fins with 50% Staggering

The above mentioned arrangements will be experimented under a heater input of 50W, 100W and 150W.

B. *Procedure*

1) Before taking the actual readings, all connections are made and checked.
2) The base plate is kept inside the siporex brick.
3) The thermocouples are connected at their respective points.
4) The heater is heated by supplying a.c.current through dimmerstat and wattmeter.
5) After checking all the connections, the switch of temperature indicators and dimmerstat is turned ON.
6) The temperatures at different points were read by the digital temperature indicator and were recorded at a time interval of 30 minutes.
7) The final reading was recorded when steady state is reached.

C. Sample Calculations

For Heater Input – 50W
Type of Configuration - Staggered-Fins

1) *Area of Plate (A) – 0.15 x 0.1 = 0.015 m2*
2) *Conduction loss-*

Bottom Loss

$$= AK\ Brick\ ((T11-T12) / dx) \quad (1)$$

Side Loss 1

$$= AK\ Brick \times 2\ ((T13-T14) / dx) \quad (2)$$

Side Loss 2

$$= AK\ Brick \times 2\ ((T15-T16) / dx) \quad (3)$$

$$Qrad = \sigma AE\ (T^4s - T^4_\infty\ ) \quad (4)$$

3) *Convection loss-*

From above we can calculate Convection loss as following

$$Qheater = Q\ Conv + Qrad + Q\ cond \quad (5)$$

4) *Heat transfer coefficient*

$$Q\ Conv = hA\Delta T \quad (6)$$

5) *With the help of above data we can also calculate Nusselt Number (Nu), Grashof's Number, Prandtl Number, Rayleigh's Number.*

V. RESULTS & DISCUSSIONS

Effect of Heater Input on Average Heat Transfer Coefficient:It has been observed from the observations that as the heater input increases, the temperature difference also increases. The temperature difference for Base plate is in the range of 29.40 °C to 70.74 °C. The variation of heater input with the temperature difference for Base Plate is shown in the graph 5.1. From the graph, it has been observed that there is a considerable rise in temperature difference with rise in heater input.

Graphs 5.2 show the variation of heater input with the temperature difference for all the other remaining arrangements. However, the temperature difference for Base plate with Horizontal Fins is in the range of 26.83 °C to 68.95 °C. For Base Plate with 33% Staggered fins, the temperature difference is in the range of 28 °C to 70.98 °C. For Base Plate with 40% Staggered fins, the temperature difference is in the range of 26.22 °C to 69.84 °C. For Base Plate with 50% Staggered fins, the temperature difference is in the range of 22.68 °C to 62.14 °C.

It has been observed that, the temperature difference is lowest for Base Plate with 50 % Staggered fins. This also tells us that there is a better performance with 50% Staggered fins as compared to the other arrangements.

However as the temperature difference increases, this also increases the heat transfer coefficient. It has been observed that the average heat transfer coefficient for Base plate is in the range of 30.56 to 39.90 W/m2 K. For Base Plate with Horizontal Fins, it is in the range of 33.52 to 40.95 W/m2 K. For Base Plate with 33 % Staggered Fins, it is in the range of 34.05 to 41.05 W/m2 K. For Base Plate with 40 % Staggered Fins, it is in the range of 35.31 to 41.49 W/m2 K. For Base Plate with 50 % Staggered Fins, it is in the range of 41.15 to 46.41 W/m2 K.

It is seen that, for 50 % Staggered Fins arrangement, the average heat transfer coefficient is the highest. Therefore, this arrangement will be the optimum arrangement as compared to the other arrangements made in this dissertation work.

A. Combined Graphs:

1) *Effect of Heat Input on Temp.Difference*

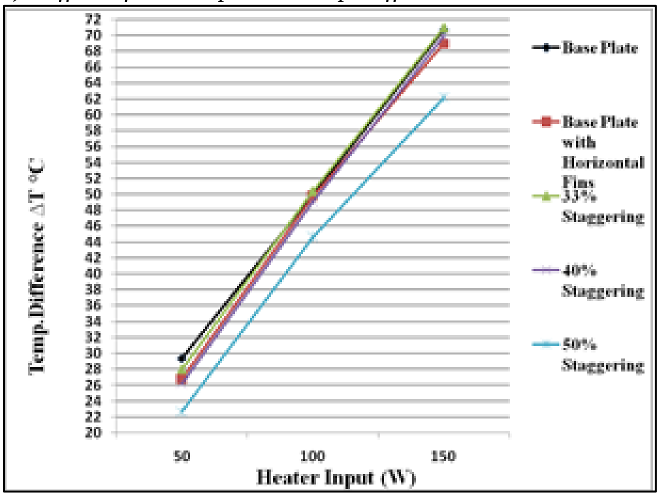


Fig. 2.1: Temperature vs Heat input

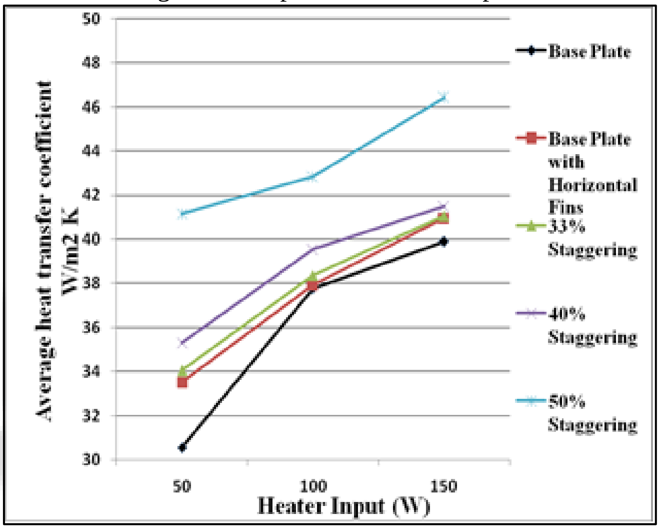


Fig. 2.2: Average heat transfer Coefficient vs Heat input

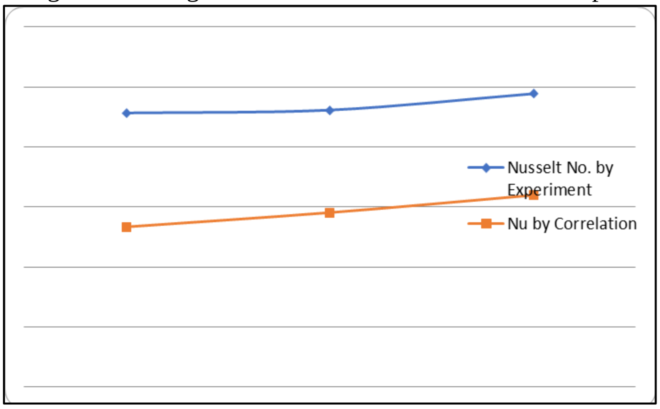


Fig. 2.3: Nusselt Number by Correlation: For 50 % Staggering

VI. CONCLUSION

The present project work is concerned with Experimental Investigation of Natural Convection Heat Transfer with Staggered Fins. Normally in the present work, the fins are staggered with various arrangements. Also, the percentage of staggering has been increased and therefore it is been assessed experimentally.

In this chapter, the main conclusions drawn on previous experimental investigations are given in the succeeding section.

1) In case of 50 % Staggered arrangement, as the fins are arranged, they have higher performance.
2) As the heater input increases, the temperature difference also increases, and it is observed that for 50 % staggered arrangement, the temperature difference is the lowest. This means that this configuration gives the better performance.
3) The average heat transfer coefficient value for 50 % Staggered arrangement is also higher as compared to other arrangements. As the heater input is increased, the average heat transfer coefficient also increases. So 50 % staggered arrangement is the best arrangement.
4) Also Nusselt number is higher for 50 % Staggered arrangement as compared to other arrangements.

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