EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER FOR OPTIMIZING FIN SPACING IN HORIZONTAL RECTANGULAR FIN ARRAY UNDER NATURAL AND FORCED CONVECTION & VALIDATION USING CFD.

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Abstract: A systematic experimental investigation of the fin spacing for the given fin height, fin length , for the width of array and heat input on free and forced convection heat transfer from horizontal fin array was carried out. A horizontal rectangular fin array with aluminum fin and aluminum spacer is constructed in which the distances between the fins are varied with adding or removing the spacers of different thickness between the fins. The objective of this experimentation is to determine the optimum spacing in which the maximum heat transfer is taking place by natural and forced convection at different heat input and at different wind velocity.
Keywords: Fin array, Heat Transfer coefficients, Natural Convection, Flow pattern, flow visualization.

I. INTRODUCTION

Fins are extensively used to remove the heat from the automobile engines, air craft engines, cooling of generators, motors, transformers, refrigerators, cooling of computer processors and other electronics devices. The failure rate of electronic equipment increase exponentially with the temperature. Also the high thermal stresses in the solder joints of the electronic components mounted on circuit board resulting from temperature variation are major causes of failure. Therefore thermal control of the circuit board has become an important factor in the design and operation of the electronic equipment. The current trend in electronic industry is microminiaturization of the electronic equipments. The thermal design problem is recognized as one of the limiting factor for achieving the higher packaging density. Natural convection cooling with the help of the finned surfaces often offers an economical and trouble free solution in many situations. Fin array on horizontal and vertical surface are used in variety of engineering applications to dissipate heat to surrounding. The only controlling variables in the hands of the designer are orientation and geometry of the fins to maximize the heat transfer. For effective dissipation of heat, plain horizontal surfaces facing upward are preferred since they provide relatively higher surfaces heat transfer coefficients than other orientations. Since the heat transfer coefficients are strongly depends upon the mechanism of the fluid flow, a thorough understanding of the resulting of the fluid flow patterns from the fin array is also of much use of the designer. The problem of the natural convection heat transfer from a rectangular fin array on a horizontal base surface has been investigated experimentally.

II. LITERATURE REVIEW

Experimental work on horizontal fin arrays was studied by various authors. Starner and McManus [1] was the first one on the topic of natural convection heat transfer from rectangular fin arrays on horizontal surfaces. The purposed of investigation was to experimentally determined average heat transfer coefficients for rectangular fin arrays of various dimension. Harahap and McManus [2] extended the work of Starner and McManus with object of more fully investigating the other objectives of their study were to investigate flow field. The other objectives of their study were to investigate flow field. Jones and Smith [3] undertook their investigation with prime objective of establishing the optimum spacing of fins for maximum transfer from given base surface. They experimentally determined averaged heat transfer coefficient for horizontal arrays over a wide range of spacing. Mannan [4] studied the effect all pertinent geometrical parameter of fin array on its performance. His work covered wide range of length: 127 mm to 508mm, height: 254mm to 1016mm and spacing: 4.8mm to 28.6mm with temperature difference varying from 39 oC to 156 oC. Sane and Sukhatme [6] considered the situation of an isothermal rectangular fin array on a horizontal surface. Vinod Wankar, Dr. S.G.Taji [9] investigate flow pattern through rectangular fin under natural convection. Nusselt number for 10mm fin spacing was 58.35. The highest value of ha is 5.7929 W/m2 K at the spacing of 12 mm. Maximum value of Nu for fin spacing 10mm was found 58.35

III. OBJECTIVE OF THE WORK

From the literature survey it is observed that different researchers uses different size of horizontal rectangular fin array , different types of fin shapes and different sizes and shapes were cut to investigate the heat transfer problems and analyzed the effect of different parameters like length, height spacing on heat transfer coefficient. All of them gone up to certain spacing, but nobody have investigated the optimum spacing between the fins for getting the maximum heat transfer coefficient. So in this experimental work, we are going to investigate, what is the optimum spacing for the highest heat transfer coefficient for the given size of fin array.

IV. EXPERIMENTAL SETUP

Experimental setup is constructed on the basis of simplicity and practicability. Fin flats are manufactured using 2 mm thick commercially available aluminum sheet cut to the size of 250 X 85 mm. Spacers are cut from same aluminum sheet. Some spacer of 2mm, 3 mm and 5mm thickness are also cut of 250X35 and in required quantity. Basic dimension of fin array used for experimentation are L=250 mm, W=100 mm, H=50 mm. These dimensions are decided by taking into account the convenience of measurement of surface temperature, input wattage as well as location of thermocouples so as to observe flow pattern by using simple smoke technique. This experiment deals with the study of natural convection, proper care is taken to avoid any effect of turbulent air flow around the fin array. An enclosure is fabricated in the formed of cubical with a volume of approximately 1 m3. Three wall of cubical are enclosed with plywood sheets and front wall with acrylic sheet. Top of the enclosure is kept open for undisturbed natural convection. The base plate of fin array was heated using cartridge type heater, which were given stabilized power input using dimmerstat. For realistic temperature measurement of the fin surface and ambient temperature, sixteen calibrated Cu-Constantan 36 gauge thermocouples, mounted at appropriate location are used. In order to account for heat dissipated by radiation black coating (using the black soot by burning camphor) is used. Syporex block placed at bottom and side of assembled array make provision four thermocouple to account the conduction loss through bottom and sides of the arrays. Two thermocouples are attached to the Bakelite plate to measure temperature. Schematic diagram of experimental setup showing electrical connection is shown in Fig 1. The fin array assembly is mounted inside the cavity of syporex block is as shown in Fig. 2.

Fig.1. Assembly of the fin array

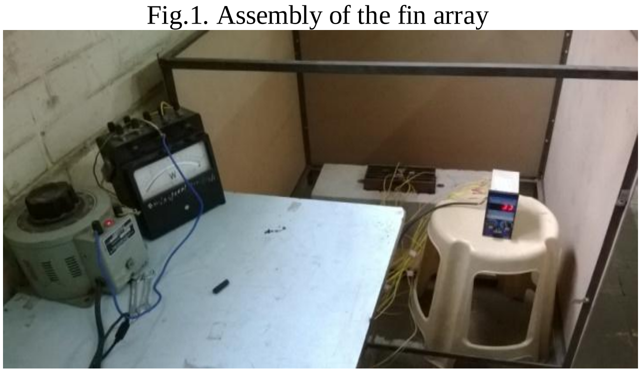


Fig. 2 Experimental setup

Fig. 3. Fin array assembly is mounted inside the cavity of syporex block and chimney for forced convection

V. EXPERIMENTAL PROCEDURE

1. Fin array was assembled, thermocouples and heaters are attached and placed in the position, and connections are made as per requirement.
2. The predetermined heater input was adjusted with the help of dimmer stat.
3. The temperatures of assembled fin array at different positions and ambient temperature were recorded at the time intervals of 30 min. up to steady state condition. Generally it took 3 to 4 hours to attain steady state conditions in natural convection and 2 to 3 hours in force convection.
4. The heater input was kept constant by adjusting the dimmer stat for voltage fluctuations if any.
5. The Temperature reading are taken for the different heat input, at different spacing and heat transfer coefficient is calculated and plotted against the fin spacing.

VI. CFD MODELING AND SIMULATION

The CFD modeling, simulation and post processing are carried out in GAMBIT 2.4.6 and FLUENT 6.3, Workbench environment with an ANSYS system of fluid flow (CFX), It has the capability of solving the convective transport of energy by fluid flow along with the conjugate heat transfer (CHT) capability to solve the thermal conduction in solids. Geometry was created using GAMBIT Modeler software which is specifically designed for the creation and preparation of a geometry for simulation. A domain has to be built around the fin to study mass flow and thus the heat flow from the fin, because the area of interest is the outside of fin, which is the interface between the air and fin surface. Thus, connections are required between the solid fin surface and the fluid domain consisting of air. GAMBIT is a software package designed to help analysts and designers build and mesh models for the computational fluid dynamics (CFD) and other scientific application. GAMBIT GUI receives user input by means of its graphical user interface (GUI) . The GAMBIT GUI makes the basic steps of building, meshing, and assigning zone types to a model simple and intuitive, yet it is versatile enough to accommodate a wide range of modeling application. It enables an automatic tetrahedral mesh generation using efficient mesh generation techniques, meshes were created with high contact sizing relevance (dense meshing near the fin surface), total number of tetrahedral elements between 45000 to 60000. Temperature distribution and heat flux along the fin surface as well as parameters like Nusselt Number, heat transfer coefficient, and changes in other parameters can also be predicted by computational analysis as shown in following fig.

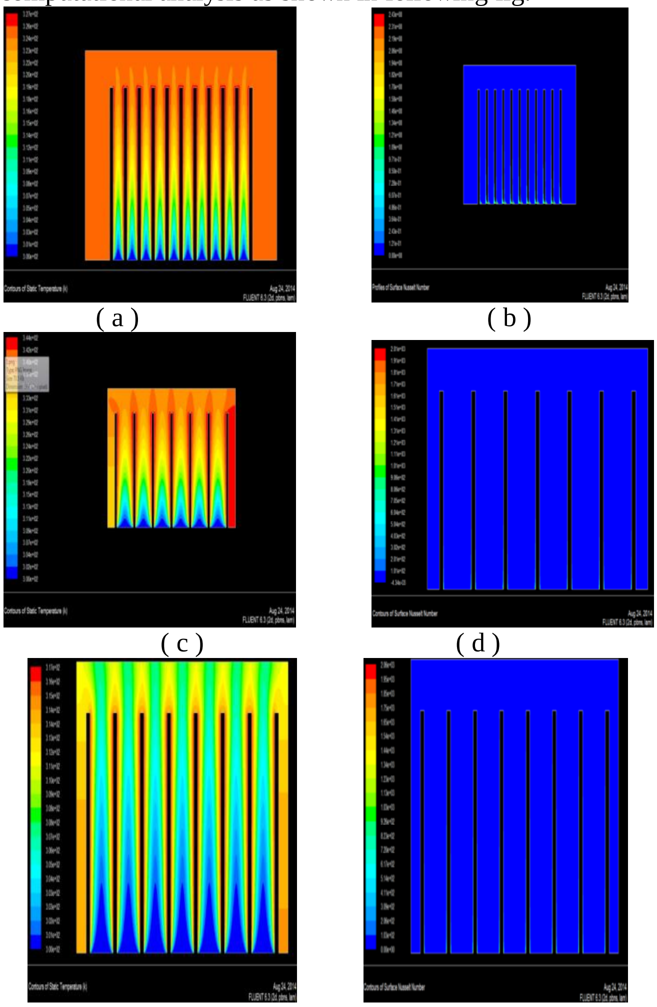
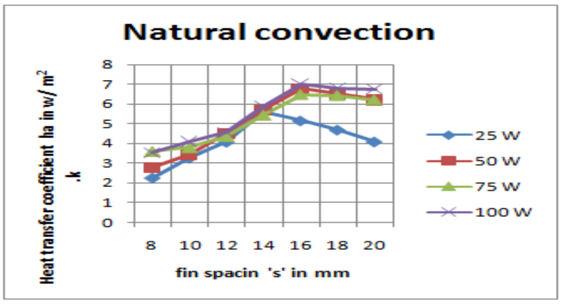
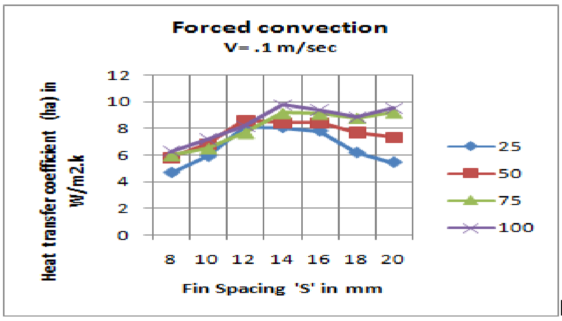


Fig. 4. Flow simulation at different spacing
(a) Contours of the static Temp. in S_8_H_50
(b) Profiles of Surface Nusselt Number
(c) Contours of the static Temp. in S_16_H_50
(d) Profiles of Surface Nusselt Number
(e) Contours of the static Temp. in S_14_H_50
(Forced Convection)
(f) Profiles of Surface Nusselt Number

VII. RESULTS AND CONCLUSION

Results were obtained and presented in the form of various heat transfer parameters. It is concluded that, the values of average heat transfer coefficient ha increases as the distance between the fin increases but this trend does not remain same and later heat transfer coefficient decreases after the fin spacing of 16 mm .The average heat transfer coefficient is maximum when the spacing between the fin is 14 mm to 16 mm. Later the average heat transfer coefficient decreases as the fin spacing increases. But in case of the forced convection the maximum heat transfer coefficient is obtained between the fin spacing of 12 mm to 14 mm. and near about 36 % heat transfer is increased in case of the forced convection. This increase in heat transfer coefficient is due to increase in air flow over the surface.





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