



INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X

Impact factor: 4.295

(Volume 4, Issue 2)

Available online at: www.ijariit.com

Experimental investigation of heat transfer by natural convection through staggered fin array at different positions

Akhilesh Patil

akhiborn2win@gmail.com

G. H. Raisoni College of Engineering and Management,
Pune, Maharashtra

S. H. Gupta

saurabh.gupta@raisoni.net

G. H. Raisoni College of Engineering and Management,
Pune, Maharashtra

ABSTRACT

The special surface arrangement of fins or special fin geometry may enhance heat transfer rate. Staggered arrangement of fins is the special fin arrangement which gives enhanced heat transfer coefficient essential due to effective flow distribution. The arrangement selected for topic is experimental investigation of staggered fin arrays. They are compared with different fin array. The fin arrangement under study have constant length, width, fin thickness with different fin spacing. The design of fin arrays includes four types of arrangements i.e. continuous, 33.33%, 40% and 50% percentage lengthwise staggering of vertical fin arrays and with 38 and 48mm fin height on horizontal plate. The fin arrays with continues type compared with three lengthwise staggering are investigated experimentally under natural convection for different heater inputs and observations. The average heat transfer coefficients and average Nusselt number are calculated for each array also respective graphs are plotted. The results are presented by the calculation of Nusselt number verses product of Grashoff number and Prandtl number graphs. Also the results classified with flow visualization techniques. The work classified with calculating that heat transfer increases with increasing percentage staggering in staggered arrangement of fins.

Keywords: Heat Transfer, Natural convection, rectangular perforated Fins, Staggered Arrangement etc.

1. INTRODUCTION

The fins have important applications in many fields so heat transfer using the fins has been the topic of interest of many researchers including heat exchangers, hot water and steam pipes, heaters, refrigerators, chemical processing systems and electrical conductors. Using the heat transfer rates results in saving of power supplied and increased efficiency in case of the automobile engines, computer chips, etc. Due to the high demand of lightweight, compact, and economical fins, the optimization of the fin size have great importance. Fins have extended surface and they are used in many industries to increase the heat transfer rate. There are various types of fins but due to simplicity rectangular plate fins are commonly used. Natural convection from a block with fins may be used to simulate wide variety of engineering applications as well as provide better insight into more complex systems of heat transfer such as heat exchangers, refrigerators, electric conductors, etc. Heat transfer rate in convection can be increased by use of staggered fin. There are much more situations where heat is to be transferred between a fluid and a surface.

For heat transfer in fluid and surface cases the heat flow depends on three factors:

- (i) area of the surface
- (ii) Temperature difference and
- (iii) the convective heat transfer coefficient.

The base surface area is limited by design of the system. The temperature difference depends on the process and that cannot be changed. The only choice appears to be the convection heat transfer coefficient and this also cannot be increased beyond a certain limit. Any such increase will be at the expense of power for fans or pumps. Hence possibility of increasing surface area is in extended surface. The main aim of the study is to design fins for optimising the use of a given amount of material for maximise heat transfer. For this purpose it will be necessary to have the fin surface temperature is closer to the base surface temperature. This can be achieved by the use of materials of high thermal conductivity like copper or aluminium. In terms of weight and ease of lubrication aluminium will be the better option than copper though its thermal conductivity will be lower. Fins are mostly used in

heat exchanging devices for increasing the heat transfer between surface and the surrounding fluid. A pin fin is a cylinder or other shaped element attached perpendicular to a wall.

The heat transfer in microelectronic heat sink applications is very useful as per their design and thermal analysis. The increase of heat dissipation from microelectronic devices and the considerable reduction of their sizes increase complications in the design of microelectronic elements that emphasizes the need for better thermal management of the concerned parts. This is mainly achieved by increasing heat released from a heat sink to ambient by increasing the surface area which is in direct contact with the coolant. This can also be achieved by increasing the coolant velocity or by modifying the geometries of heat sinks. Fins are widely used in trailing edges of gas-turbine blades, in electronic cooling and in aerospace industry.

These are types of fin geometries:

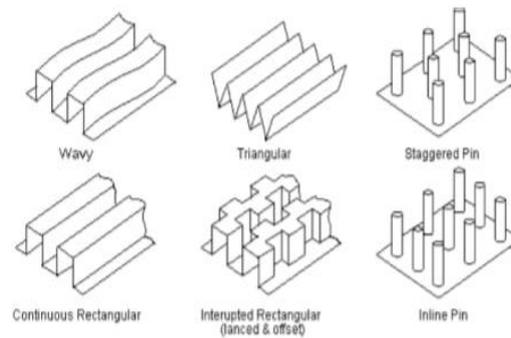


Fig.1 Types Of Geometry of Fins

There are different types in arrangement of geometry:

- Plain arrangement
- Perforated Arrangement

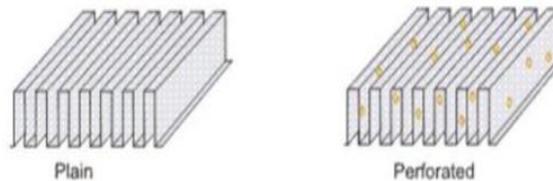


Fig .2 Arrangement of Fin Geometry

2. LITERATURE REVIEW

Ambrish maji et al states that their work investigates the heat transfer enhancement of heat sink using perforated pin fins with linear and staggered arrangement. Pin fins of various shapes with different perforation geometries namely circular, diamond shaped and elliptical type are considered in this analysis. Three dimensional CFD simulations have been performed to study the effects of number and shape of the fin, geometry and dimension of the perforation for both the arrangements. Perforated fins are placed both in inline and staggered manner. The dissipation in results shows higher rate than solid ones with the variation in fin shape and perforation geometry heat transfer rate improves. better system performance is observed for staggered arrangement than in line.[1]

Tzer ming zeng et al states they studied pressure drop and heat transfer of square fin in rectangular channel by using transient single bow technique. The different parameters which are variable are relative longitudinal pitch ($XL= 1.2, 2,2.8$) relative transverse pitch ($XT= 1.5,2,2.8$) and the arrangement. They compared square fin with circular fin.The fin pitches are relatively smaller here so he then provided with optimal internal fin pitches and found that square fins performs the best. They even concluded that pressure drop and heat transfer in lesser in in line square fin than in line circular fin.[2]

Nimesh Limbasiya et al studied the heat transfer in heat sinks of microelectronic components has been numerically analyzed for different heat sink geometries in tandem and staggered arrangements. The present study is about cooling of fins with forced air convection in single micro channel heat sink using Ansys FLUENT software. Standard and staggered fins of uniform thickness are considered for all the heat sinks to analyze heat transfer performance. Quality factors corresponding to different geometries were calculated and compared with experimental and numerical results available in open literature. The present numerical results ensure the better performance of staggered heat sinks over standard ones. It has been noticed that staggered fins with conic section provide enhanced quality factors at flow Reynolds number range of 450 – 900 whereas staggered fins with rounded leading edges provide better thermal performances for Reynolds number beyond 900. Four different kinds of fins having rectangular, rounded leading edge, parabolic and conic cross sections arranged in standard and staggered manner are considered for analysis. The fins arranged in staggered manner are formed to experience higher cooling rates than the standard fins of similar cross sections.

However, fins with rounded leading edge and conic sections were observed to impart higher cooling efficiencies than the other configurations.[3]

Shyy Woie chang et al states that they studied vertical fin array with and without dimples for steady state 3 dimensional natural convective flow and heat transfer. For study 4 different vertical fins used whose name are smooth thirteen fin array, smooth nine fin array, dimpled nine fin array, dimpled seven fin array. These vertical fins are analysed for free convective flow and heat transfer for varying Rayleigh number and fixed Prandtl number. They concluded that the Rayleigh number increases over each type of surface as Nusselt number increases. Air velocity is low at bottom of fin than tips so it generates accelerating flow through channels. With F3 dimpled configuration strong free convective flows are developed resulting to high Nusselt number than other arrays. The dimpled fin F3 array gives high value of Nusselt number.[4]

Sagar I. Shah states that fin is heat-sinks that have extend surface from its base. It enhances the rate of heat transfer. They discussed in this paper about different types of geometry and arrangements like Drop fin, Elliptical fin. Fin winglet, pin fin with dimple, plane fin, wavy fin etc. Pin fin has a better capacity of heat transfer then the flat plate. Also when we are using different types of plate with dimples, distance between two consecutive pins and whole, rectangular pin or cylindrical pin, winglet type fins etc. This paper is concentrated only on heat exchanger heat transfer who discussed about how to increase the heat transfer rate with using different types of fins and in which is the best for high heat transfer in different applications. They concluded that heat transfer rate increases in geometrical way of Wavy, triangular, staggered, continuous, interrupted and increasing order of heat transfer is plain, perforated, serrated, heringbon. For better heat transfer in line and perforated are suitable.[5]

K.M.Kelakar studied heat transfer and fluid flow in 2 dimensional laminar flow. Two parallel plates maintained at constant temperature and staggered fins are attached on that. Calculations were performed for different values of the Reynolds number, the Prandtl number, geometric parameters, and the fin-conductance parameter. Fins gives the deflection in flow and that strikes on opposite wall to increase heat transfer rate. It is observed that the heat transfer rate is more for the fluid which have high Prandtl number. When the Prandtl number is low, it is found that the use of short fins may indeed decrease the heat transfer.[6]

Ankur Kumar et al states the investigation of characteristics in circular and plat fins. At constant Raynolds number heat transfer coefficient decreases with increase in spacing. Results are given in compactness of heat exchanger. Wavy fins produces high heat transfer coefficient and pressure drop is higher for circular fins due to their longer flow path. Friction factor for crimped and serrated fin is higher than plate fin indicating obstruction in flow. They studied 3 fin patterns in detail. It is also observed that all plate fins with crimped fins can provide much compact heat exchanger design compared to serrated and plain circular fin. The capital and operating cost can be minimised by circular fins.[7]

3. PROBLEM DEFINITION

Experimental investigation of heat transfer by natural convection through staggered fin array to get optimum fins for maximum heat transfer rate at different positions.

4. METHODOLOGY USED

- Defining the problem and literature review.
- Studying natural convection and basics in detail for calculation purpose.
- Preparing prototype model.
- Carrying out experiment.
- Calculations and finding optimum fins.
- Ploting graphs.
- Results and discussion.

5. EXPERIMENTAL LAYOUT

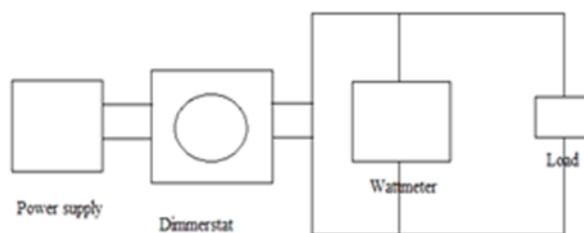


Fig.3 Experimental Layout Block Diagram



Fig.4 Experimental Layout Block Diagram

6. EXPERIMENTATION FACILITY

- Staggered fins with base plate
- Control Panel and thermocouples
- Enclosure
- Siporex box, heater unit and wooden block

1. Staggered fins with base plate

It consist of rectangular base plate having the dimension 200 mm x 180 mm, thickness is 35mm and it mounted in siporex box the staggered fins and base plate made of the Aluminium material because of the considerations of conductivity, machinability and cost. Spacing between the fins is constant equal to 34 mm. First we using continues array i.e. four plates of 200 mm wit thickness 2mm and having height 38mm for 1st reading and 48 mm for 2nd reading. Four sets of fin arrays are of 38 mm height and remaining four are of 48 mm. Then again lengthwise staggering started first we doing 33.33% staggering for both heights and taking readings. After that again this procedure repeated for 40% and for 50% lengthwise staggering. Total fin length is 200mm hence each piece is of 66.67mm,40 mm and 20mm for 33.33% ,40% and 50% lengthwise staggering respectively as shown in fig.

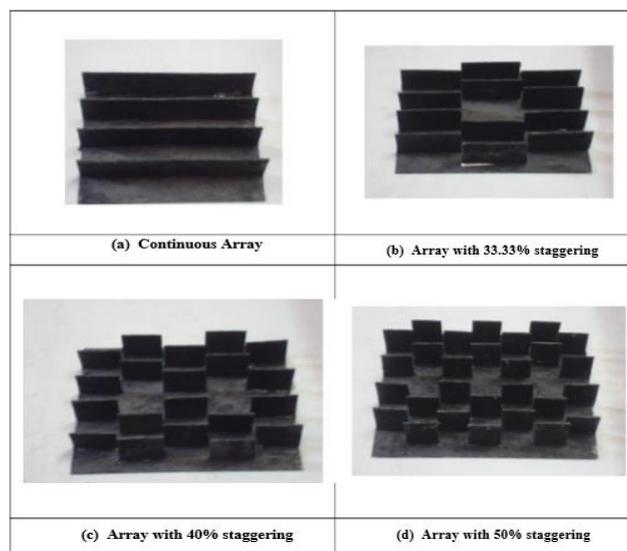


Fig. 5 Staggered Plates

2. Control Panel and Thermocouples

It consists of switch, dimmerstat, Wattmeter, Temperature indicator. MCB switches are used to cut off the power supply in case any short circuit. Dimmerstat having range from 0 to 4 Ampere (0 – 230V) are used for setup. Wattmeter showing actual power of input send to the heater having range minimum 0 - 300 watt for setup we having range 0- 600 watt thats enough. Temperature indicator having range to show 0-300°C but we using K type Chromium-Aluminium(Cr-Al) thermocouple so we using Chromium-aluminium temperature indicator having range 0°C to 1200°C. The device which indicates the reading taken by the various component like Thermocouples, Siporex box, insulation cover also wood box are used in experimental setup. There are eleven

thermocouples are used with range 0°C to 300°C they all K-type thermocouples(Cr-Al type).control panel shown in below fig and thermocouples are shown in experimental setup figure.



Fig.6 Components of Control Panel

3. Enclosure

It is used to resist the extra flow of wind in the atmosphere to the setup. It consists of 2 wooden plates one from right and one left side of setup and in front and back fibre glass for visualization of flow pattern in staggered fins as shown in figure. This enclosure is more important and effective in the process of any experimental investigation in natural convection. Also beneficial advantage is because of enclosure we can visualise the pattern of flow from the staggered fins in natural convection.



Fig.7 Enclosure

4. Siporex box, heater unit and wooden block

Siporex box is used for insulating material for base plate. Base plate is mounted in siporex box having dimensions 300 x 260 x 145mm. It having holes for the velocity of air by natural convection from base plate also heater unit is under that base plate in my base plate or experimental setup three heaters are used for calculations which are 100mm long with 20mm diameter and connected to wattmeter i.e. input power supply where we calculate the readings with taking 4 parameters 25,50,75,100, 125 watt. Also we put three wooden boxes one on right and second on left side siporex box and another base of siporex box this is for loss of conduction through that siporex box. So we get accurate readings of for experiment and investigation for natural convection went right and get accurate calculations.all shown in fig.





Fig.5 Siporex

7. DATA COLLECTION AND ANALYSIS

This chapter includes steps involved while carrying out the experiment, observations of the experimentation and the methodology to determine heat transfer coefficient.

Procedure

The experimentation is carried out for finding average heat transfer coefficients for each above mentioned fin array. The step by step procedure adopted is as follows.

Place the array under study in the test section.

Switch on electric supply and adjust the heater input to defined value with dimmerstat and record with the help of voltmeter and ammeter.

Provide the constant heater input for 6 to 8 hours so that steady state is attained.

Record 11 different thermocouple readings as specified in the observation table.

Observations

Following are the common observations for each set.

Distance between holes in siporex box (x_b) = 0.025 m

Thickness of wooden insulation (t_w) = 0.018m

Area of base (A_b) = $l \times b = (0.2 \times 0.18) = 0.036 \text{ m}^2$

Average area of fin (A_a) = $A_b + 5(l \times h) \times 2 = 0.036 + 5 \times (0.038 \times 0.2) \times 2$ [For 38 mm height Arrays]

Average area of fin (A_a) = $A_b + 5(l \times h) \times 2 = 0.036 + 5 \times (0.048 \times 0.2) \times 2$ [For 48 mm height Arrays]

Fin Material = Aluminum

8. RESULTS

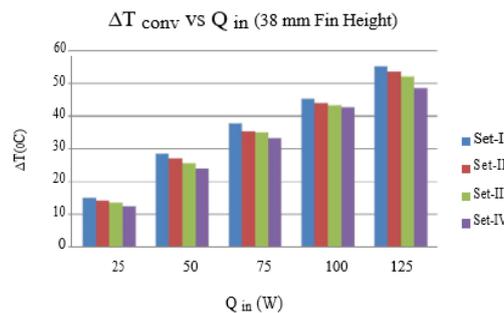


Fig.6 Variation of Temperature Difference Verses Heat Input For 38 Mm

9. CONCLUSION

- Experimental study of staggered fin arrays is performed using two different heights of fin flats. The percentage lengthwise staggering and heat input are varied.
- Staggered arrays under study are tested under natural convection and compared with continuous fin array.
- The arrangement for 38 mm with 50% staggered arrangement gives better heat transfer rate is concluded.

10. FUTURE SCOPE

The work provided in this thesis provides an effective comparison of staggered fin and continuous fin arrays. The proposing problems for the future study are given below,

- Theoretical Analysis of staggered fin arrays.
- Experimental analysis of variable spacing in staggered fin arrays.
- The CFD analysis to observe actual flow pattern.

10. REFERENCES

- [1] Ambarish Majia, Dipankar Bhanjaa, Promod Kumar Patowari; 'Numerical investigation on heat transfer enhancement of heat sink using perforated pin fins with inline and staggered arrangement', Department of Mechanical Engineering, National Institute of Technology Silchar. S1359-4311(2017)34484-8.
- [2] Tzer ming Jeng; 'Pressure drop and heat transfer of square pin fin arrays in in-line and staggered arrangements', Department of mechanical engineering. International journal of Heat and Mass transfer 50(2007)2364-2375.
- [3] Nimesh Limbasiya, Arnab Roy, Atal Bihari Harichandan; 'Numerical Simulation of Heat Transfer for Microelectronic Heat Sinks with Different Fin Geometries in Tandem and Staggered Arrangements', Department of Mechanical Engineering, Marwadi Education Foundati. S2451-9049(2017)30063-X on Group of Institutes, Rajkot, India.
- [4] Shyy Woie chang, Da-Yu Guo; 'Heat transfer enhancement of vertical dimpled fin array in natural convection', Department of Marine engineering. Heat transfer enhancement 2016.
- [5] Sagar I. Shah; 'Effect of Geometry and Arrangement of Pin Fin in Heat Exchanger: A Review', Asst. Prof., Department of Mechanical Engineering, Atmiya institute of Technology and Science Rajkot, Gujarat, INDIA. February 2016, Volume 3, Issue 2.
- [6] K. M. Kelkar, S. V. Patankar; 'Numerical Prediction of Flow and Heat Transfer in a Parallel Plate Channel With Staggered Fins', Department of Mechanical Engineering, University of Minnesota. FEBRUARY 1987, Vol. 109/25.
- [7] Ankur Kumar, Arun K Nayak; 'A comparison of various hydraulic performance of various fin patterns using 3D CFD simulation', Homi Bhabha National Institute Mumbai. International journal of heat and mass transfer 109(2017)336-356.