Design & Analysis of Natural Convection Heat Transfer in a Rectangular Finned Heat Sink

Thara R[1] Lohitesh Jaga Kumar[2] Naveen Kumar[3] Dr. Irfan G[4]
[1,2,3]Assistant Professor [4]Dean & Head of Dept.
[1]CIT, GUBBI India [2,4]AIT, Tumkur India [3]Kuppam Engineering College – Kuppam India

Abstract— In Natural convection heat transfer with the help of fin arrays, parameter are fin length to height ratio, spacing and orientation of geometry. In the longitudinally short fin array, where single chimney flow pattern is present hence heat transfer coefficient is high. In long rectangular fin arrays, air is stagnant at central zone hence it is not so much contributed in heat dissipation. In present study experimental setup is developed to studying the effect of natural convection over rectangular fin array. Fin spacing, height and heater input are the parameter study during experimentation. Lampblack coating is used to black fin surface. Flow patterns of various spacing's are investigated using smoke flow visualization techniques. Most of the studies on natural convection have been considered constantly whereas velocity and temperature domain, do not change with time, transient one are used a lot. Governing equations are solved using a finite volume approach. The convective terms are discretized using the power-law scheme, whereas for diffusive terms the central difference is employed. Coupling between the velocity and pressure is made with SIMPLE algorithm. The resultant system of discretized linear algebraic equations is solved with an alternating direction implicit scheme. Then a configuration of rectangular fins is put in different ways on the surface and heat transfer of natural convection on these surfaces without sliding is studied and finally optimization is investigated.

Key words: Rectangular Finned Heat Sink, Natural Convection Heat Transfer

I. INTRODUCTION

Cooling Electronic components using natural convection is considerably more challenging than forced air cooling. That is because the thermal resistance of a heat sink may be up to 20% higher in a natural convection environment than in a high-air speed environment. The various heat sink configurations are frequently encountered in the natural convection cooling of electrical equipment ranging from transformers to main frame computer and from transistors to power supply.

II. LITERATURE REVIEW

Mahdi Fahiminia et.al (2011) computationally analyzed laminar natural convection on vertical surfaces. CFD simulation carried on a configuration of rectangular fins put in different ways on the surface and natural convection heat transfer coefficient on these no slope surfaces is studied. From results it can also be seen that, at a given fin height and temperature difference, the convection rates increases with increasing fin spacing and reaches a maximum. With further increases of fin spacing, rate starts to decrease. The occurrence of this maximum has significant practical applications for optimum performance of fin-arrays and finally optimization is done.

Shivdas S. Kharche and Hemant S. Farkade (2012) investigated experimentally and theoretically natural convection heat transfer from vertical rectangular fin arrays with and without notch at the center. Moreover notches of different geometrical shapes have also been analyzed for the purpose of comparison and optimization. They observed that in a lengthwise short array where the single chimney flow pattern is present, the central portion of fin flat becomes ineffective due to the fact that, already heated air comes in its contact. From the experimental study it is found that the heat transfer rate in notched fins is more than the un-notched fins.

N.G.Narve et.al., (2013) conducted experiments on heat transfer characteristics of natural convection heat flow through vertical symmetrical triangular fin arrays and its results were compared with equivalent rectangular fin arrays. Results were generated for S= 0.015, 0.03, 0.045 & 0.105 and GrH =2*107 to 5*107. Average, base Nusselt number and Grashof number were calculated. It was observed that with increase in Grashof number, average and base Nusselt number increases. Similarly average Nusselt number increases with spacing whereas base Nusselt number increases to maximum value with spacing and then decreases.

III. EXPERIMENTAL EQUIPMENT AND INSTRUMENTATION

The experimental set-up is made for making measuring on rectangular heat sinks. The experimental set -up primarily consists of various instruments for measuring the ambient temperature, base-plate temperature and the power input for the heater. A schematic view of the interconnections between the instruments used in the experimental set-up is shown in Figure 1. Figure 2 shows a photograph of the experimental set-up and the instrumentation.

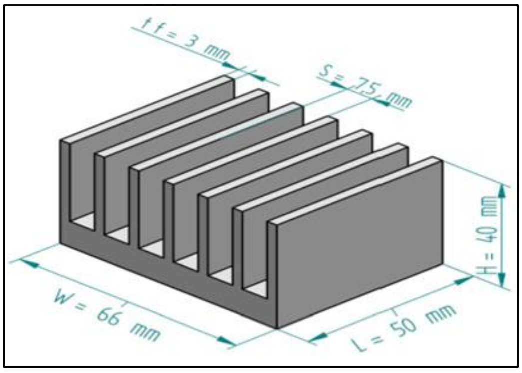


Fig. 1: Schematic View of the Experimental Set-up

During the experiments, voltage and current measurements and temperature measurements were performed in order to supply desired power inputs to the heaters and read the ambient temperature and the temperature values at various locations on the fin base -plates. The electrical power was supplied through a regulated AC supply. The output of supply was fed to variable transformers or autotransformer so that, the power inputs could be varied as desired.

The voltage across the heater coil and the current passing through it are indicated by the digital voltmeter and ammeter. The digital voltmeter with a scale 0-200V indicates the voltage values with a 4-digit display and accuracy of one decimal place. The digital ammeter with a scale 0-10A indicates the current values with a 4-digit display and accuracy of two decimal places. The temperature indicator used in the temperature measurements has 4-digit display and accuracy of one decimal place. The minimum accuracy needed by the above instruments was determined after making an uncertainty analysis for computation of the heat transfer coefficient.

IV. EXPERIMENTAL METHODS

In order to be able to determine the convective heat transfer performance of the finned heat sink under steady-state conditions the following procedure was followed. The method used for determining the heat transfer coefficient is to supply a known heat input to the heater coil and measure the temperature attained by the heat sink. Before undertaking the experiments an uncertainty analysis was performed to determine the effect of each of the parameters involved on the uncertainty in the heat transfer co-efficient values. The steps given below were followed.

Time t, (s)	T1 (°C)	T2 (°C)	T3 (°C)	T4 (°C)	T5 (°C)	T6 (°C)	Ta1 (°C)	Ta2 (°C)
100	69	67.6	57	63.9	67.3	69	40	41.2
200	70	68.4	57.1	64.1	67.6	71	40.3	41.3
300	70.2	68.5	57.1	64.2	67.7	71.2	40.3	41.4
400	70.4	68.8	57.4	64.2	68.3	71.4	40.6	42.3
500	70.8	69.5	57.5	64.6	68.6	71.6	41	42.8
600	70.9	69.5	57.9	64.9	68.9	71.9	43	43.8
700	71	70.1	58	65.3	69.3	71.9	44	44.2
800	71	70	58.2	65.6	69.4	72	45	45.3
900	71	70.21	58.2	66	71.2	72.3	45.1	45.4
1000	71.3	70.4	58.6	66.4	71.4	72.3	45.4	46
1200	71.5	70.6	59	66.8	71.6	72.6	46	46.3
1400	71.9	71	59.6	68	70.8	72.3	46.2	46.6
1600	72.5	71.1	60.3	68.3	72	72.7	46.8	47
1800	73	72.4	61.3	69.8	72.6	72.9	47.6	47.9
2000	73.7	72.9	61.6	70.1	73	72.8	48.1	48
2200	74.1	72.9	62	70.6	73.3	72.3	48.8	49.2
2400	74.4	73.5	62.3	70.9	73.2	72.4	49.3	45.4
2600	74.5	73.5	62.3	71	73	72.5	49.9	50.2
2800	74.4	74.1	62.5	71.1	72.9	72.8	51.2	51.5
3000	74.4	74	62.5	71.3	72.9	72.6	51.2	51.5
3200	74.2	74.2	62.6	71.3	73.2	72.4	51.6	51.8
3400	74	73.7	62.7	71.4	72.8	72.6	51.6	51.8
3600	74	74	62.6	71.7	72.9	72.1	52	52.3
3800	73.9	73.8	62.5	71.8	73. 1	72.3	52.3	52.6

Table 1: A typical Temperature History for Heat Sink with S/H =0.25

- A.C. power is supplied to the heater coil from mains through a stabilizer and UPS which, in turn, is connected to an auto-transformer.
- The voltage V and current I are set at the required values and the temperature readings of the all the thermocouples T1, T2, T3, T4,T5, T6, Ta1 & Ta2 are noted.

V. EXPERIMENTAL RESULTS AND DISCUSSION

Experiments conducted in the present work are summarized as follows. All the results presented in this work are for Heat sink with fins in vertical orientation. The experiment is confined with certain variable to perfectly guide the experiment into achieving the objectives. By doing so, the experiment can be done in brief and the result can be gained easily. Conduct experiments for different fin array geometry and orientation using the test bench available in Thermodynamics laboratory. Evaluate the heat transfer coefficients. Validate the results. On the basis of evaluating the heat flow of the rectangular fin array through free convection, it is important that all the parameters is identified and measured, through the experiment then only the evaluation of temperature can be done. Observed the temperature difference and validate with theoretical analysis.

A. Computational Software

This section describes the fluent software required for carrying out a simulation and the process that are required to solve a problem using CFD. There is a variety of commercial CFD software available such as Fluent, Ansys CFX, ACE, as well as a wide range of suitable hardware and associated costs, depending on the complexity of the mesh and size of the calculations. In this thesis which we have used solid work software for the simulation.

B. Meshing of the Domain

The second part of pre-processing is the mesh generation. After the model is imported to workbench it is then launched in the meshing module for the mesh generation Coarse, medium, and fine mesh types are available. Mesh density varies based upon the assigned Refinement Factor. Mesh is the key component of a high quality solution. There are three kinds of meshing algorithms. These are Hexahedral Cartesian, Hexahedral Unstructured and Tetrahedral meshers. Hexahedral Cartesian mesher is the one generating fully structured meshes. It is suitable for very limited type of geometries. It is generally inappropriate for models where curved surfaces exist. Hexahedral Unstructured mesher creates grids of hexahedral cells dominantly and tetrahedral cells where necessary. Tetrahedral mesher is designed for very complicated geometries where the other two cannot be used. For models involving spheres or ellipsoids hexahedral meshers are useless. In our problem CFD unstructured mesher is used.

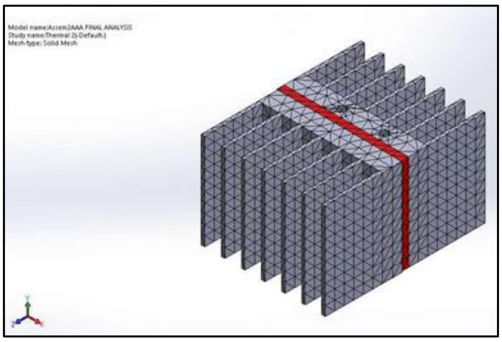
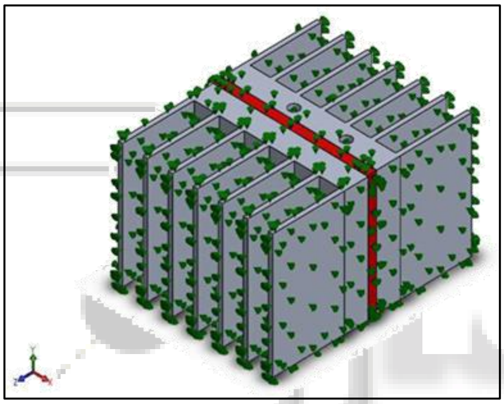


Fig. 2: Meshed Fin

C. *Analysis Result*

Analysis for the Al 6063-T83
Model Information



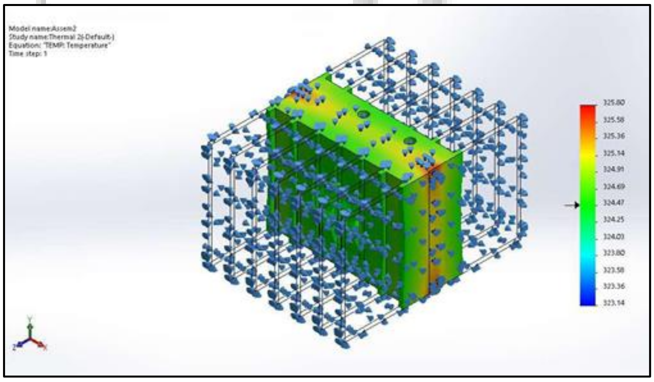


Fig. 3: Analysis Result

VI. CONCLUSION

For all the two profiles compared for the maximum temperature attained on the basis of result governed by the CFD analysis, with the fin pitch of 3mm the rectangular heat sink shows the maximum temperature attained as compared to the parabolic heat sink and the parabolic heat sink shows the highest maximum temperature attained which is not desirable. Heat transfer co-efficient and Nusselt number is maximum in rectangular heat sink for the given fin pitch and the heat load of 40W.

As per the criterion for the selection of heat sink, the heat sink should have lowest thermal resistance and maximum heat transfer co-efficient. The rectangular heat sink shows the lowest thermal resistance and the maximum heat transfer co-efficient. From the calculated values we can find that the best configuration for this type of convective heat transfer of a heated sink is a heat sink with rectangular fin with a fin pitch of 3mm as they have the highest total heat transfer rate as it has the lowest maximum temperature attained compared to other, lowest thermal resistance best Nusselt number along with the highest surface heat transfer co-efficient for a given heat load of 40W.

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