Numerical Study of Heat Sink Performance for Varying Number of Fins for Constant Fin Volume and Constant Fin Thickness

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Abstract: ***Heat sinks are devices which absorb and dissipate excess unwanted heat. They help in maintaining temperature of a component within safe limits. The design of heat sink is critical as it effects the performance of the heat sink. The optimum design will dissipate the maximum amount of heat and at the same time will be compact and cheap to produce. This paper aims at studying the performance of heat sink for varying number of fins in two cases, viz. first by varying number of fins keeping fin volume constant and second by varying number of fins keeping fin thickness constant. For this study we have considered the case of a free convection heat sink for an electronic chip with heat load of 10 Watt. The number of fins is varied for each case keeping all other parameters constant and the maximum temperature of the chip is plotted.***

Keywords: Heat sink, Fin geometry, Free convection, Conjugate heat transfer

1. Introduction

As electronic components become increasingly powerful and capable, the heat load of the component goes on increasing. Also the size of these electronic components is to be kept small to maintain compactness of the final product. Thus, large amount of heat is to be dissipated within a small space and hence the heat sink should be designed taking into consideration the compactness of the design. Thus layout becomes an important aspect to be looked into when designing a heat dissipating system. Octavio Leon, Gilbert De May and Erik Dick studied the optimum layout for cooling fins by minimising the flow resistance across the fins [1]. R. L. Linton and D. Agonafer studied coarse and detailed modelling of finned heat sink [2]. They also compared the results of CFD model with experimental results. R. Boukhanouf and A. Haddad did CFD analysis of an electronic cooling enclosure for telecommunications systems [3]. Most studies are conducted for straight rectangular fins, however Sheam-Chyun lin, Fu-Sheng Chuang and Chein-An Chou conducted their study on oblique fins and compared them with similar straight rectangular fins [4]. B. YazicioğluH and Yüncü studied the effect of fin height and spacing for varying heat loads [5]. Ricardo Romero-Méndez, Mihir Sen, K.T. Yang and Rodney McClain studied the effect of fin spacing for a fin and tube heat exchanger [6] .Also another aspect to be taken into consideration is the ease of manufacturing and cost. The design of the heat sink should be such that is should be easy to manufacture and also inexpensive to produce. Heat sinks absorb heat from the heated component by conduction and then dissipate the heat to the surrounding by convection. To maximise dissipation of heat, the heat sinks are designed such as they have a high convective heat transfer co-efficient and subsequently maximum area available for heat dissipation. In our study we have used a 40 mm x 40 mm x 5 mm electronic chip with a heat load of 10 Watt attached to a heat sink with varying number of fins. Here, the convective heat transfer co-efficient is increased by manipulating the shape of the heat sink and area is increased by providing fins. Thus the heat from the chip is transferred to the heat sink by conduction which in turn is dissipated to the surrounding by the fins. The dimensions of the chip, outer dimensions of the heat sink and the heat load is fixed and only internal parameters, namely number of fins, spacing and orientation are manipulated to find optimum design.

2. Methodology

The objectives of this paper are as follows:

a) To study the effect of increasing the number of fins and heat sink orientation on chip temperature, keeping volume of fins constant.
b) To study the effect of increasing the number of fins and heat sink orientation on chip temperature, keeping fin thickness constant.

Different combinations of above cases are simulated with the same boundary conditions and the maximum chip temperatures for each case is tabulated. The heat sink geometry and orientation for every case is changed and the problem is simulated using Acusolve. This gives us the effect of every parameter. Each simulation has three stages, namely pre-processing, solving and post-processing.

Pre-processing involves setting up the problem by defining the geometry, mesh parameters and boundary conditions. It is the process of defining input parameters for the problem. The geometry consists of a 40 mm x 40 mm x 5 mm electronic chip mounted on a heat sink with base area of 100mm x 100mm and thickness of 5 mm.

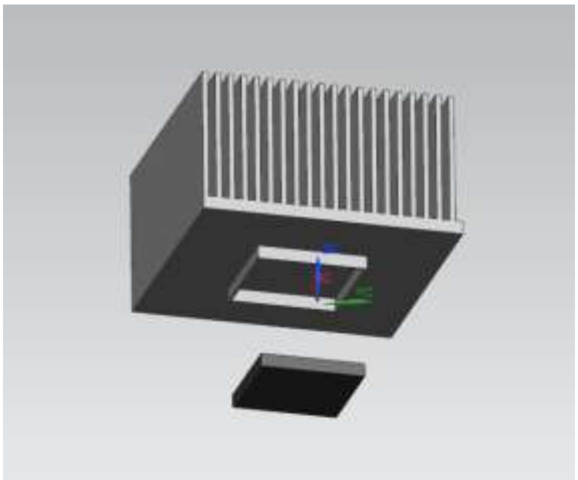

Figure 1: Heat sink geometry

The geometry is meshed using AcumeshSim with relative mesh size of 0.1. Also there is a boundary layer near every solid surface in the fluid domain. A boundary condition of 10 W is given to chip volume and material properties of aluminium are assigned to heat sink and that of air to as ambient environment. The problem is then solved using Acusolve solver and the results are viewed in Acufieldview.

3. Results

The results have two parts namely; (1) effect of increasing the number of fins and heat sink orientation on chip temperature, keeping volume of fins constant and (2) effect of increasing the number of fins and heat sink orientation on chip temperature, keeping fin thickness constant. For each condition, three different orientations of the heat sink and nine variations in number of fins are considered. So for each condition 27 cases are analysed by varying number of fins and orientation. The three different orientations are considered as shown below:

Plate horizontal with fins vertical:
In this case the plate on which the chip is mounted is placed horizontally so the fins are aligned vertically. Here the free convection flow around the chip is obstructed from flowing upwards by the plate but the air around the fins is convected upwards as can be seen from the figure 2.

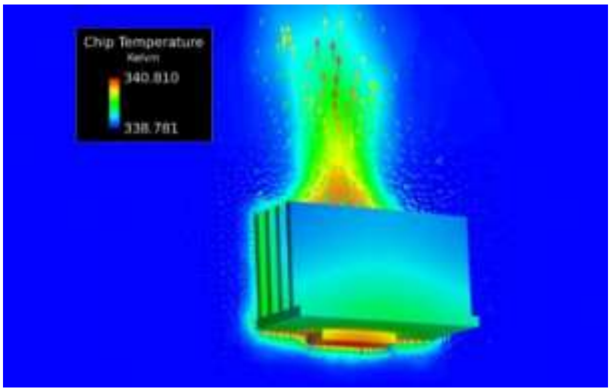

Figure 2: Plate horizontal with fins vertical

Plate vertical with fins perpendicular to free convection flow:
In this case the plate on which the chip is mounted is placed vertically and the fins are aligned perpendicular to free convection flow. Here the air around the chip is convected upwards but the air around the fins is obstructed as shown in figure 3.

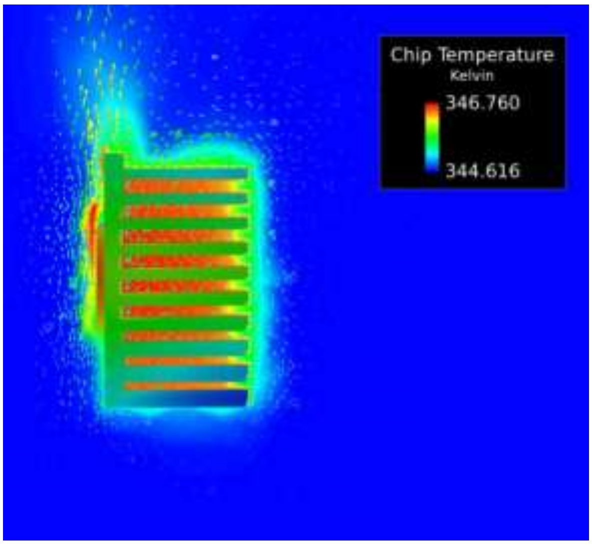

Figure 3: Plate vertical with fins perpendicular to free convection flow

Plate vertical with fins parallel to free convection flow:
In this case the plate on which the chip is mounted is placed vertically and also the fins are parallel to the upward free convection flow. Here both the air around the chip as well as the air around the fins is can flow upwards on account of free convection as there is no obstruction as shown in figure 4.

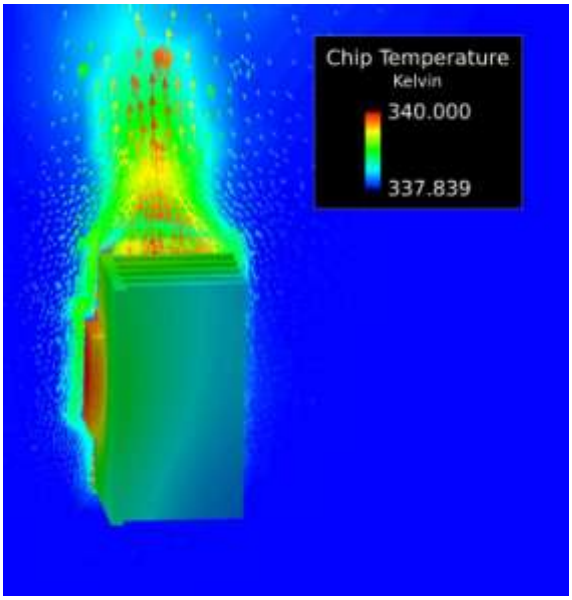

Figure 4: Plate vertical with fins parallel to free convection flow

3.1 Effect of Changing Numbar of Fins and Orientation Keeping Total Fin Volume Constant

In this condition the number of fins is increased keeping the total fin volume constant. Thus on increasing the number of fins, the thickness of each fin and the spacing between them is decreased in order to maintain same volume. Also for every case of a given number of fins, the problem is simulated for the above mentioned three possible orientations. The chip maximum temperature for every case is tabulated in the below table. Parameters like fin spacing, cross sectional area and volume are also tabulated to give better idea of variation of fin geometry. The fin spacing is governed by the number of fins. The fin height and total cross sectional area is kept constant to maintain same total volume in every case. However the total surface area of the fins increases on increasing the number of fins as shown in the table 1.

Table 1: Temperature vs. Number of fins for constant fin volume

					Chip Maximum Temperature		
Number of fins	Fin spacing(mm)	Total fin cross section area (mm²)	Fin volume (mm³)	Fin surface area (mm²)	Plate horizontal, fins vertical (° cel)	Plate vertical, fins perpendicular to free convection flow (° cel)	Plate vertical, fins parallel to free convection flow (° cel)
No fins	N.A.	4000	200000	20000	93.858	94.177	94.177
10	10	4000	200000	104000	67.66	73.61	66.85
20	5	4000	200000	204000	59.58	62.891	60.437
40	2.5	4000	200000	404000	49.093	49.438	49.017
80	1.25	4000	200000	804000	39.735	39.742	39.69
160	0.625	4000	200000	1604000	34.062	34.05	34.055
200	0.5	4000	200000	2004000	32.644	32.629	32.633
250	0.4	4000	200000	2504000	31.599	31.591	31.594
320	0.3125	4000	200000	3204000	30.616	30.607	30.61

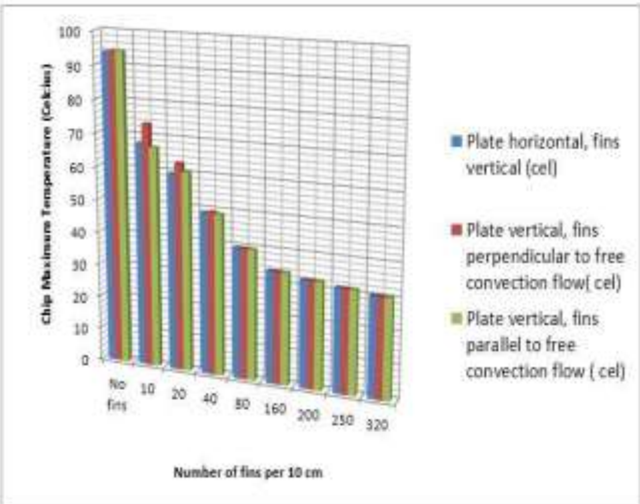

Figure 5: Temperature vs. Number of fins for constant total fin volume

3.2 Effect of Changing Number of Fins and Orientation Keeping Fin Thickness Constant

In this condition the number of fins is increased keeping the fin thickness constant at 1 mm. In this case, the number of fins is increased by decreasing the spacing between them. Hence on increasing the number of fins, the total volume of fins increases along with the total surface area available for convection. Again, for every case of a given number of fins, the problem is simulated for the above mentioned three possible orientations. The chip maximum temperature for every case is tabulated in the table 2. Parameters like fin spacing, cross sectional area and volume are also tabulated to give better idea of variation of fin geometry.

Table 2: Temperature vs. Number of fins for constant fin thickness

					Chip Maximum Temperature		
Number of fins	Fin spacing (mm)	Total fin cross section area (mm²)	Fin volume (mm³)	Fin surface area (mm²)	Plate horizontal, fins vertical (° cel)	Plate vertical, fins perpendicular to free convection flow (° cel)	Plate vertical, fins parallel to free convection flow (° cel)
10	9	1000	50000	101000	88.156	103.125	91.111
20	4	2000	100000	202000	71.828	80.463	73.76
30	2.33	3000	150000	303000	53.78	54.501	53.909
40	1.5	4000	200000	404000	48.959	49.097	48.993
50	1	5000	250000	505000	45.424	45.404	45.426
60	0.67	6000	300000	606000	42.75	42.733	42.761
70	0.43	7000	350000	707000	40.708	40.693	40.71
80	0.25	8000	400000	808000	39.112	39.088	39.093
90	0.11	9000	450000	909000	37.804	37.77	37.804

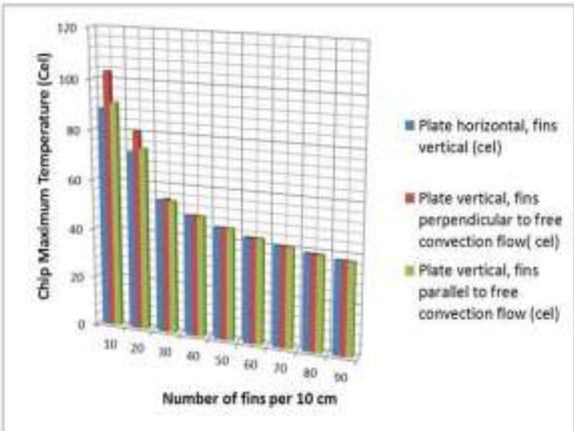

Figure 6: Temperature vs. Number of fins for constant fin thickness

4. Conclusions

From both the above graphs, it is evident that the temperature is higher for the orientation in which the plate is vertical and the fins are perpendicular to the flow of free convection. This is because the fins obstruct the free flow of lighter air upwards leading to localised heated zones between the fins. This reduces the heat dissipation thus decreasing heat sink performance. The other two orientations have almost identical temperatures suggesting that they have similar performances. This is because in both the orientations, the fins are parallel to the free convection flow of warmer air upwards thus dissipating heat at a faster rate compared to perpendicular fin orientation. Another observation is that as the number of fins is increased, the temperature of the chip drops; which is logically expected as the total surface area available for convection increases with increase in number of fins. However, it is interesting to note that the drop in temperature itself decreases as we increase the number of fins. Thus the chip temperature remains almost constant even on increasing the number of fins, when the fins are densely packed. This is because when the fin spacing becomes very low, the air in between the fins can’t flow freely, thus reducing heat dissipated by convection.

References

[1] Octavio Leona, Gilbert De Meya, Erik Dick, "Study of the optimal layout of cooling fins in forced convection cooling", Microelectronics Reliability, 2002, Pages 1101–1111
[2] R.L. Linton , D. Agonafer, "Coarse and detailed CFD modeling of a finned heat sink", IEEE Transactions on Components, Packaging, and Manufacturing Technology, 1995, Pages 517-520.
[3] R. Boukhanoufa, A. Haddadb, "CFD analysis of an electronics cooling enclosure for application in telecommunication systems", Applied Thermal Engineering, 2010, Pages 2426–2434.
[4] Sheam-Chyun Lin, , Fu-Sheng Chuang, Chien-An Chou, "Experimental study of the heat sink assembly with oblique straight fins", Experimental Thermal and Fluid Science, 2005, Pages 591-600.
[5] B. YazicioğluH. YüncüEmail,"Optimum fin spacing of rectangular fins on a vertical base in free convection heat transfer", Heat and Mass Transfer, 2007, Pages 11-21.
[6] J Ricardo Romero-Méndez, Mihir Sen, K.T. Yang, Rodney McClain, "Effect of fin spacing on convection in a plate fin and tube heat exchanger", International Journal of Heat and Mass Transfer, 2000, Pages 39-51.

Author Profile

Keith Francis Chakramakkil received his B.E. degree in Mechanical Engineering from Don Bosco Institute of Technology, Mumbai in 2015 and M.Tech. degree in Mechanical Engineering specialising in CAD/CAM and Automation from Veermata Jijabai Technological Institute, Mumbai in 2017. During June 2016 to July 2017, he worked as an intern in Larsen & Toubro, Heavy Engineering Division working on Thermal and Flow Analysis of Unmanned Aerial Vehicle Systems which was also his M.Tech Thesis. He is now with Stryker Corporation as an Associate Design Engineer.