OPTIMUM DESIGN AND SELECTION OF HEAT SINK

1Mukesh Kumar 2 Anil Kumar 3Sandeep Kumar

1Asst.Prof. in Shivalik Institutes of Engg. & Tech.-Aliyaspur
2, 3Asso. Prof. in Modern Institute of Engg. & Tech. - Mohri

ABSTRACT

The study of heat sink is an important field for the last decade. The reason is mainly the possibilities of reducing the size, weight and cost as compared to current designs. Also, new applications, heat sinks have been gradually developed so as to satisfy these needs. The continual development of faster desktop computers being sold at lower prices into the market place has demanded that thermal management engineers develop and optimize thermal management devices that not only perform better, but are at the same or lower cost than previous generations. The ever shrinking form factor has also increased the burden placed on today's thermal management devices.

Keywords: Heat sink, CFD, fins, heat transfer

1. INTRODUCTION

Advancements in semiconductor technology have led to the significant increase in power densities encountered in microelectronic equipment [1]. As the amount of heat that needs to be dissipated from electronic devices constantly increases, the thermal management becomes a more and more important element of electronic product design. Both the performance reliability and life expectancy of electronics equipment are inversely related to the component temperature of the equipment. Therefore, long life and reliable performance of a component may be achieved by effectively controlling the device. Operating temperature within the limits set by the device design engineers. With the increase in heat dissipation from the electronic devices and the reduction in over all form factors, it became an essential practice to optimize heat sink design with least trade-offs in material and manufacturing costs. A study of heat sink fin technologies has given in formation towards important design criteria for practical cooling of electronic components. Significant work has been carried out by various researchers in the thermal analysis of heat sink design. Ellison [2], Kraus et al. [3] have presented the fundamentals of heat transfer and hydrodynamics character of heat sinks including the fin efficiency, forced convective correlations, applications in heat sinks, etc. Sasaki [4] optimized, with criteria of fin to channel thickness ratio of unity, the dimensions of water cooled micro-channels at a given pressure. Azar et al. [5] reported a method of design optimization and presented contour plots showing the thermal performance of an air cooled narrow channel heat sink in terms of fin thickness and channel spacing parameters and employed Poiseuille’s equation in relating the channel flow velocity to the pressure drop, and the optimization method was presented, as summing the pressure drop across the heat sink is known. An analytical method of optimizing forced convection heat sinks was proposed by Knight et al. [6, 7] for fully developed flow in closed finned channels. They presented normalized non-dimensional thermal resistances as a function of the number of channels, again for a fixed pressure drop. Wirtz et al. [8] investigated experimentally the effect of flow by pass on the performance of longitudinal fin heat sinks and Devised a set of expressions for determining the optimum fin density for different fin geometry and flow conditions. Keyes [9] analytically examined the fin and channel dimensions to provide optimum cooling under various forced convection cooling conditions. Bartilson [10] investigated, using both experimental and numerical techniques, air jet impingement cooling on a rectangular pin fin heat sink. Various shapes of longitudinal straight fin heat sinks were experimentally examined, and the thermal performance measurements were compared with existing correlations [11]. Seri Lee [12] observed that the actual convection flow velocity through fins is usually unknown to designers, yet, is one of the parameters that greatly affect the overall thermal performance of the heat sink and developed a simple method of determining the fin flow velocity and the Development of the overall model of the heat sink. Different types of heat sink are examined, and their relative performances are presented. The analytical simulation model is validated by comparing the results with the experimental data, and sample cases are presented with discussions on the parametric behavior and optimization of bi-directional heat sinks with the heaters placed symmetrically. Chris to pher et al. [13] studied on elliptical pin fin heat sink. Comparative thermal tests have been carried out using aluminum heat sinks with extruded fins, cross cut
rectangular fins in low air flow environments. Besides the thermal measurements, the effect of air flow by pass characteristics in opened duct configuration was investigated. The testing described in the study incorporates several possible performance factors into two terms; flow by pass and over all thermal resistance. These simplified terms represent a combination of several factors, such as material conductivity, lateral fin conduction, boundary layer formation, effective surface area, and pressure drop. The cross cut heat sink of fersease of production assembly where misalignment of heat sink with respect to the direction of the air flow will result in failure. Voliaro et al. [14] and Culham et al. [15] studied the optimization of the parallel plate heat sink and at tempted to define general rules for optimizing it. Park et al. [16] and Culham et al. [15] studied the optimization of the parallel plate heat sink and attempted to define general rules for optimizing it. Park et al. [16] proposed the progressive quadratic response surface model to obtain the optimal values of design variables For a plate fin type heat sink Park et al. [17, 18] performed an investigation of numerical shape optimization for high performance of a heat sink with pin fins. Yu et al. [19] developed a plate pin fin heat sink and compared its performance with a plate fin heat sink. Chiang et al. [20] developed the procedure of response surface methodology for finding the optimal values of designing parameters of a pin fin type heat sink under constraints of mass and space limitation to achieve the high cooling efficiency. From the above literatures, it can be concluded that Significant work needs to be carried out in optimizing the heat sink design. Plate fin and pin fin heat sinks are commonly used heat sinks for electronic cooling applications. This makes the selection of heat sink a difficult task for a particular application. In the present work, cross cut pin fin heat sink is developed and its performance is compared with the parallel plate heat sink in micro electronics cooling. In most of the electronic components the heat duty involved is high and also the heater is placed symmetrically about the axis, thereby leading to space constraints. An effort is made in the experiment by placing the heating element asymmetrically for the study of heat transfer characteristics and the thermal performance. The fan distance is also varied in the experimental work to find the optimum distance for maximum efficiency for both parallel plate and cross cut pin fin heat sinks.

**Heat-Sink Types:** Heat sinks can also be classified in terms of manufacturing methods and their final form shapes. The most common types of air-cooled heat sinks include [8]

1. **Stampings:** Copper or aluminum sheet metals are stamped into desired shapes. They are used for air cooling of electronic components at low cost and low thermal density problems. They are suitable for a high volume production and advanced cooling with high speed stamping

![Stamping Heat sink](image)

2. **Extrusions:** The formation of elaborate two-dimensional shapes capable of dissipating large heat loads [16]. They may be cut, machined and options are added. A cross-cutting will produce unidirectional, rectangular pin fin heat sinks and incorporating serrated fins improves the performance by approximately 10 to 20% at the expense of extrusion rate. Extrusion limits, such as ratio of the fin height-to-gap aspect ratio. The minimum fin thickness-to-height and maximum base to fin thicknesses usually dictate the flexibility in design options.
3. **Bonded/Fabricated Fins**: Air cooled heat sinks are convection limited and the overall thermal performance of an air cooled heat sink can be improved by exposed more surface area to the air stream can be provided even at the expense of conduction paths [16]. These high performance heat sinks utilize thermally conductive aluminium-filled epoxy to bond planar fins on to a grooved extrusion base plate. This process allows for a much greater fin height-to gap aspect ratio of 20 to 40, greatly increasing the cooling capacity without increasing volume requirements.

4. **Castings**: Sand, lost core and die casting processes are available with or without vacuum assistance, in aluminum or copper/bronze. This technology is used in high density pin fin heat sinks which provide maximum performance when using impingement cooling.

5. **Folded Fins**: Corrugated sheet metal in either aluminum or copper increases surface area and, hence, the volumetric performance. The heat sink is then attached to either a base plate or directly to the heating surface via epoxying or brazing. It is not suitable for high profile heat sinks due to the availability and from the fin efficiency point of view. However, it allows obtaining high performance heat sinks in applications where it is impractical or impossible to use extrusions or bonded fins.
Folded fins

To quantify the effectiveness of different types of heat sinks, the volumetric heat transfer efficiency can be defined as:

\[ \eta = \frac{Q}{mc\Delta T_{sa}} \]

Design Parameters
In designing or selecting an appropriate heat sink that satisfies the required thermal and geometric criteria, one needs to examine various parameters that affect not only the heat-sink performance itself, but also the overall performance of the system. Option of choosing a particular type of heat sink depends largely on the thermal budget allowed for the heat sink and external conditions surrounding the heat sink. In any type of heat sink, one of the most important external parameters in air cooling is the flow condition which can be classified as natural, low flow definition or consensus on the flow velocity that separates the mixed and forced flow regimes.

A list of design constraints for a heat sink may include parameters, such as

- induced approach flow velocity
- available pressure drop
- cross sectional geometry of incoming flow
- amount of required heat dissipation
- maximum heat sink temperature
- ambient fluid temperature
- maximum size of the heat sink
- orientation with respect to the gravity
- appearance and cost

Given a set of design constraints, one needs to determine the maximum possible performance of a heat sink within the envelope of constraints. The parameters, over which a designer has a control for optimization, typically include,

- fin height
- fin length
- fin thickness/spacing
- number/density of fins
- fin shape/profile
- base plate thickness
- cross-cut patterns
- heat sink material

Characterization and Optimization of Heat Sinks
In view of achieving an optimum thermal performance, most of the parameters discussed in the previous section are interdependent of the others. It is often true that the impact one parameter has on the performance of a heat sink cannot be generalized, or even foreseen without
Specification of heat sink without cut

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length ( L )</td>
<td>78mm</td>
</tr>
<tr>
<td>Width ( W )</td>
<td>60mm</td>
</tr>
<tr>
<td>Height ( H_f )</td>
<td>25mm</td>
</tr>
<tr>
<td>Height ( H_b )</td>
<td>08mm</td>
</tr>
<tr>
<td>Thickness ( W_w )</td>
<td>01mm</td>
</tr>
<tr>
<td>Channel width ( W_c )</td>
<td>02mm</td>
</tr>
</tbody>
</table>
Concurrently considering the consequences exhibited in the other parameters. For example; a longer fin height provides additional surface area for greater heat dissipation and improves the overall thermal performance. However, if the available volumetric flow rate is fixed, the overall performance may deteriorate with the fin height; if the available pressure drop is fixed, a longer heat sink in the direction of flow may have an adverse effect on the performance by decreasing the actual velocity over the fin surfaces, and; an option of having more fins is generally viewed as a way to improve the performance. This is a very dangerous generalization, because, in most cases, having excessive fins induce a higher pressure drop across the heat sink, resulting in a severe reduction in flow velocity and/or a significant increase in flow bypass over the heat sink.
EXPERIMENTAL SETUP

Following type heat sinks are tested.

Heat sink without cut
Heat sink with one cut

Schematic diagram of experimental setup

Heat sink made of Aluminium alloy 6061. Aluminium alloy 6061 is one of the most extensively used of the 6000 series aluminium alloys. 6061 is a precipitation hardening aluminium alloy, containing magnesium and silicon as its major alloying elements. It has good mechanical properties and exhibits good weld ability. It is one of the most common alloys of aluminium for general purpose use. It is a versatile heat treatable extruded alloy with medium to high strength capabilities. Physical and Thermal properties of alloys 6061

RESULTS AND DISCUSSION

Comparison of temperature for a heat sink without cut and with one cut for 120 W consumption
Comparison of temperature for a heat sink without cut and with one cut for 100 W consumption

Experimental analysis was made for the heat transfer for a heat sink having two profiles. The following conclusions were made throughout the experimentation:

- It was observed that the temperature variation was more for a heat sink with cut as compared to heat sink without cut leading to higher heat transfer.
- An optimum selection of heat sink is to be made depending upon its industrial application

Similar trends were also observed in for various heat inputs of 80 W, 100 W and 120 W leading to that heat transfer equations and methodologies hold well for various heat sinks.

Future Scope
Present study deals with heat transfer and pressure drop at inlet and outlet of a wind tunnel with heat sink placed inside it. This study has the following future scopes:

- Present experimental set up may be extended for the study of various other types of industrial heat sinks. All the process may be repeated for evaluating the variation in friction factor, temperature drop across the heat sink, fanning factor and pressure drop.
- Whole experimentation to be repeated for varying gap between the fins of the heat sink and their effects on temperature drop and pressure drop are to be studied.
- Effects of dimensions on heat transfer rate, i.e. width and depth may be studied using different heat sinks having different dimensions.
- The effect of different kind of materials of heat sink on heat transfer rate can be studied.

REFERENCES

AUTHOR

MUKESH KUMAR ANIL KUMAR received the B.TECH. And M.TECH. Degrees in Mechanical Engineering from Amravati University and Punjab Technical University in 1998 and 2012. He is now asst. prof. In Shivalik Institutes of Engg. & Tech.-Aliyaspur

ANIL KUMAR received the B.TECH. And M.TECH. Degrees in Mechanical Engineering from Aurangabad University and NIMS University in 1998 and 2012. PHD Pursuing from Mewar University. He is now asso. Prof in MIET Kurukshetra.

ANIL KUMAR received the B.TECH. And M.TECH. Degrees in Mechanical Engineering from National Institute of Technology Kurukshetra in 2010 and 2012. He is now asst prof in MIET Kurukshetra