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Numerical Study of Optimum Heat Sink Profile

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***Abstract**: Optimum design of heat sinks are critical. Parameters such as fin profile, arrangement of fins, fin thickness, spacing, heat sink material and size can be altered to suit a given application. All these parameters affect the performance of a heat sink and dictate its cost. Hence multiple design iterations are required for finding the right parameters for an application. This paper describes the effect of heat sink profile on the performance of heat sink, keeping all other parameter like material and volume of fins constant. For this study we have used the example of a heat sink used to cool an electronic processor of 40 mm x 40 mm x 5 mm dimensions attached to a base of 100 mm x 100 mm x 5 mm. A heat load of 80 Watts is assigned to the processor along with a fan of 100 CFM and in each iteration the heat sink shape is changed and maximum chip temperature is noted.*

1. Introduction

The size of electronic components is getting smaller each day however their capabilities as a system is improving. This leads to high power electronics in smaller sizes. Thus a large amount of heat is generated in these electronic circuits within a very compact volume of microprocessors. The life of an electronic system reduces by about half for every ten degree rise in temperature, thus there is a need to effectively dissipate this heat. Therefore the temperature of electronic chips is required to be maintained within prescribed limits. This is done with the help of heat sinks. Heat sinks are finned bodies usually accompanied by a fan which help in faster dissipation of heat. Heat sinks dissipate heat by first transferring the heat from the electronic component by conduction into its fins and then dissipating that heat into the surrounding by forced convection. The design of a heat sink is very critical as it affects the performance of the het sink which in turn affects the life of the electronic component. The main parameters that affect the performance of heat sink are its size, shape, fin thickness, spacing and profile. H. Jonsson and B. Moshfegh studied the thermal performances of plate fin, strip fin and pin fin heat sinks in their paper [1]. Daeseok Jang, Se-Jin Yook and Kwan-Soo Lee studied the optimum design of radial heat sinks for high power LED applications [2]. W. A. Khan, J. R. Culham and M. M. Yovanovich studied the effect of fin geometry on performance using single sins of circular, elliptical, square and rectangular cross section [3]. J. Richard Culham, Waqar A. Khan, M. Michael Yovanovich and Yuri S. Muzychka studied the effect of material and spreading resistance in thermal design of plate heats sinks [4]. J.G Maveety and H.H Jung studied design of optimum pin fin heat sink with air impingement cooling [5]. Feng Zhou and Ivan Catton conducted a numerical study of flow and heat transfer plate fin heat sinks for varying pin cross sections [6]. M. S. Sundaram and M. Venkatesan studied performance of perforated fin under forced convection [7]. In this paper we will focus on the effect of fin profile on the performance of heat sink. For a proper comparison we have kept the geometry and heat loads same in every case. Also the fin profile is changed such that the volume of material used for fins is the same. Hence we can isolate the effect of shape of fin on the performance of the heat sink.

2. Methodology

2.1. Geometric Modelling

For every run the geometry is changed. The geometry is altered such that the total volume of the heat sink remains the same for every design iteration for a fair comparison. Following are the details of the fin profiles.

2.1.1. Rectangular Heat Sink

These are the most common and easy to produce heat sinks. They are usually used for simple and low heat dissipation free convection applications where the size of heat sink can be large. For example rectangular fins are used to cool air cooled engines in motorcycles and reciprocating pumps. For this study 20 rectangular fins of 100 mm x 50 mm cross section and 2 mm thickness were considered.

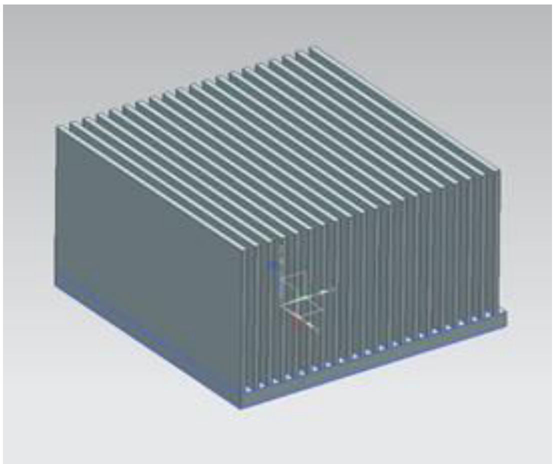

Figure 1. Rectangular heat sink geometry

2.1.2. Grid Heat Sink

Grid heat sinks are similar to rectangular heat sinks. The thin plate like fins are replaced by rectangular pin shaped fins. Grid heat sinks are used for very small electronic devices. They may or may not be accompanied with a fan. For this study 100 equally spaced fins of 40 mm2 cross section area each were considered.

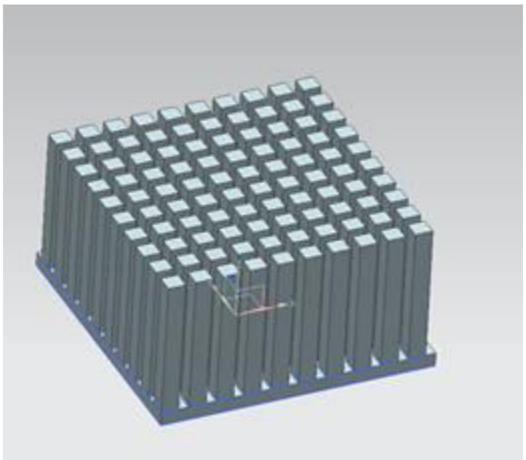

Figure 2. Grid heat sink geometry

2.1.3. Circular Heat Sink

Circular heat sinks are more commonly used in electronics along with a fan as they allow air flow into the central body of the heat sink from all directions. Circular heat sinks work very effectively in forced convection hence are usually accompanied along with a fan. For this study 20 fins of 100 mm x 50 mm cross section and 2 mm thickness arranged in a circular fashion were considered.

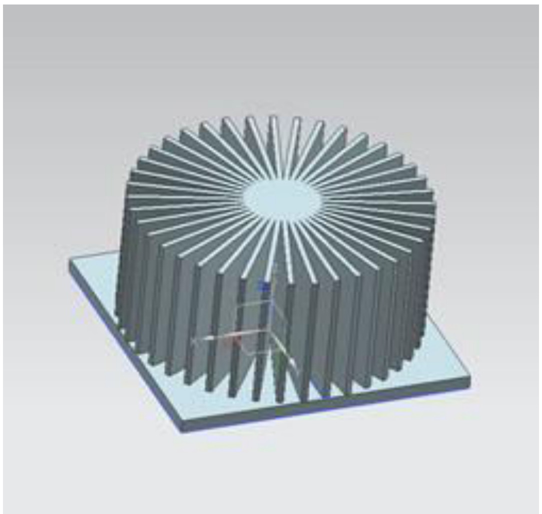

Figure 3. Circular heat sink

2.1.4. Spiral Heat Sink

A spiral heat sink is similar to a circular heat sink except for the fact that in a circular heat sink, the fins are radial originating from the centre of the circle whereas in a spiral the fins originate at an offset from the centre at a tangent to a central circle. For this study we have considered 20 fins arranged in a spiral fashion about a central circle of 20 mm diameter. The fins have a cross section of 50 mm x 50 mm and a thickness of 1.68 mm. The thickness is reduced from 2 mm as in other cases so as to compensate for increase in area due to addition of central circle so that the total volume of fin remains constant.

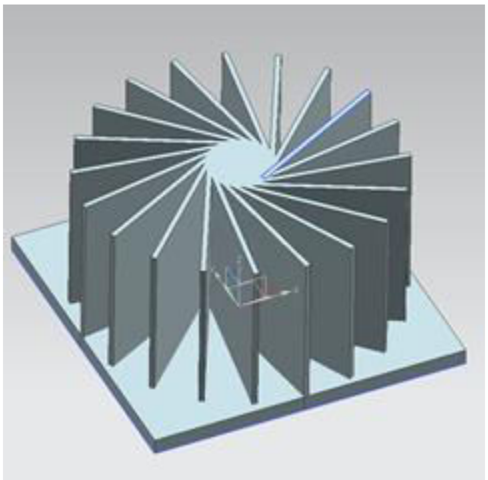

Figure 4. Spiral heat sink

2.2. Meshing and Boundary Conditions

Once the geometries are ready they are meshed using AcumeshSim with a relative mesh size of 0.1. Also boundary layers are created along every surface in the fluid domain to capture the heat transfer at the fluid-solid interface accurately. Also a flow rate of 100 CFM is given above the heat sink to simulate the effect of a fan. The boundary conditions and mesh parameters are kept identical for every iteration so that it doesn't affect the solution. The material taken for heat sink and chip is aluminium. Also there is a fan shell made of plastic on top of the heat sink. The surrounding temperature is taken as 25 degree Celsius.

3. Results

3.1. Rectangular Heat Sink

In rectangular heat sinks the air sucked in by the fan enters through the front and back faces only and not the side faces as can be seen in figure 5. The air in the side regions go around and into the heat sink from the front and back faces. The maximum temperature of the heat sink is 391.55 Kelvin.

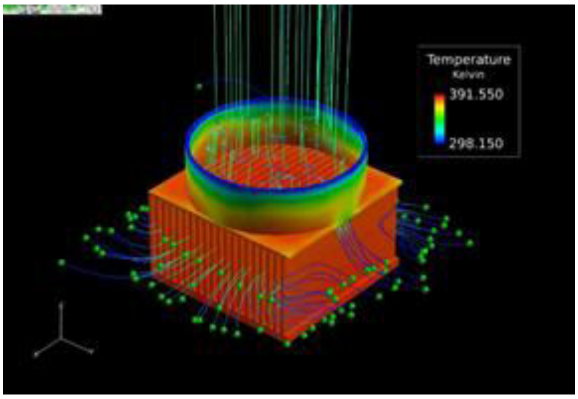

Figure 5. Rectangular heat sink temperature and flow simulation

3.2. Grid Heat Sink

The flow in the grid heat sink is from all directions into the fan region thus much less obstruction in flow. The maximum temperature of the grid heat sink is 385.052 Kelvin. The grid heat sink is cooler than rectangular heat sink due to more free movement of air through its fins.

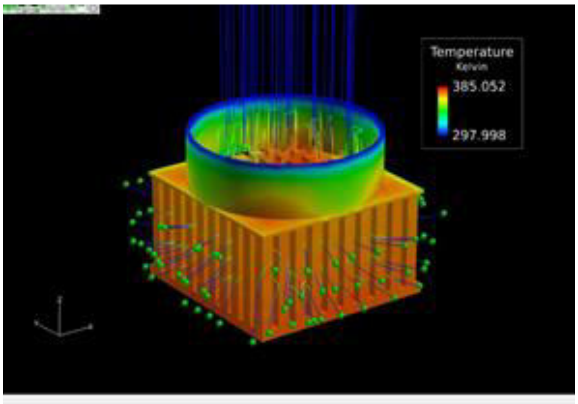

Figure 6. Grid heat sink temperature and flow simulation

3.3. Circular Heat Sink

In circular heat sink air enters the heat sink radially since the radial fins direct it that way. Thus there is minimum turbulence within the heat sink and flow is smooth. Thus circular heat sink cools much more effectively and gives a maximum temperature of 385.052 Kelvin.

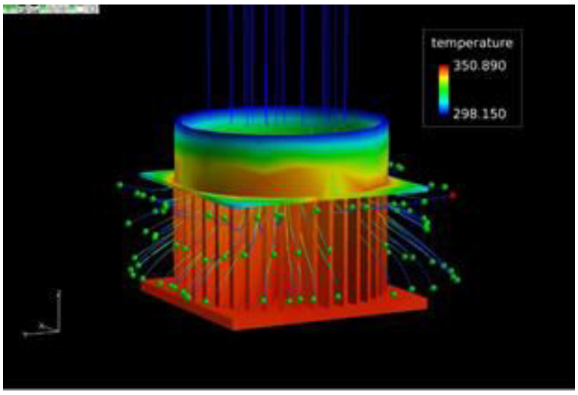

Figure 7. Circular heat sink temperature and flow simulation

3.4. Spiral Heat Sink

The flow across a spiral heat sink is very much similar to a circular heat sink, except that here enters the heat sink with a slight swirl due to the spiral profile of the heat sink. The maximum temperature of spiral heat sink is 401.506 Kelvin as shown in figure 8.

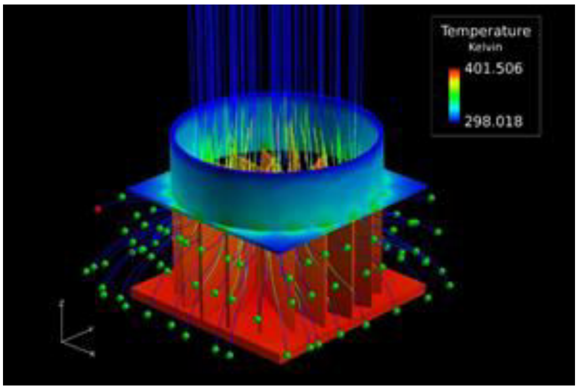

Figure 8. Spiral heat sink temperature and flow simulation

Table 1. Variation of chip temperature with heat sink profile

Heat sink profile	Fin Height (mm)	Total Cross-sectional Area (mm^2)	Total fin Volume (mm^3)	Surface Area (mm^2)	Chip Temperature (Kelvin)	Chip Temperature (Celsius)
Spiral heat sink	50	4000	200000	104616	401.506	128.506
Grid heat sink	50	4000	200000	128600	385.052	112.052
Circular heat sink	50	4000	200000	154960	350.89	77.89
Rectangular heat sink	50	4000	200000	204000	391.55	118.55

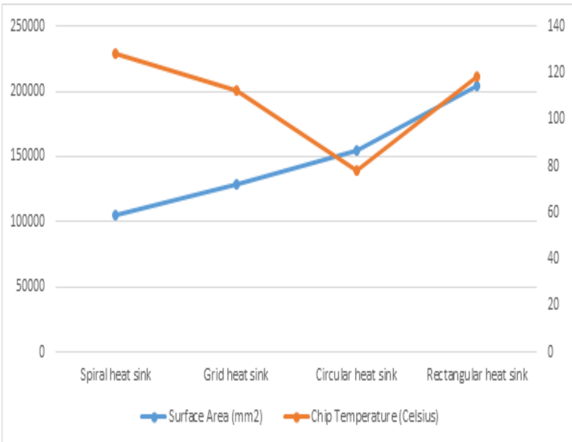

Figure 9: Variation of surface area and chip temperature with heat sink profile

4. Conclusion

In general we see that a rise in surface area is accompanied by a lower chip temperature as more area is available for dissipating heat by convection. However since this a forced convection problem the air needs to have a proper path to flow without blockage. The ease with which air flows over the fins decides the rate of heat dissipation. Hence the circular heat sink has the lower temperature since it allows air to flow from all directions into the fan however the rectangular heat sink allows air to pass through the fins only along the direction parallel to its length and blocks air perpendicular to its length, hence having a higher temperature despite higher cross sectional area. Thus performance of a heat sink not only depends on the area available for convection but also on the fin profile and their arrangement in the heat sink.

5. References

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