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# CFD analysis for rate of cooling of heat sink for CPU

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## ABSTRACT

***This paper uses CFD to identify a cooling solution for a desktop computer. In this modern world speed determines everything especially desktop PC, CPU have been popular. The computer revolution is growing rapidly in almost every field. CPU is the electronic components, which produces a lot of heat that reduces the performance. In this study the forced convection cooling of heat sinks mounted on CPU are investigated. The design is based on total chassis power dissipation. This represents significant power dissipation for the chassis components (Main processor chip, other chipsets North bridge heat sink and South bridge heat sink) the main processing chip has fin attachments (heat sink) over it for heat dissipation. There are many designs of heat sink to improve the efficiency, few heat sink designs are selected and analyzed, which would be give the maximum heat dissipation. There are many ways of cooling such as air cooling, heat pump cooling. The modified fin geometry with air cooling which is more effective and economic, since the water cooling requires water pump, a separate cooling system for coolant and a separate flow circuit. The air cooling is attained by using a cooler fan above the heat sink fins. The effect of heat dissipation and heat sink geometries are numerically analyzed by computational fluid dynamics software and fluent. The best heat sink design is selected and modified so as to attain the maximum heat dissipation. The design is able to cool the chassis with one case fan and the power supply fan. A ducted 80×60 mm CPU heat sink is able to meet the CPU temperature specification. System level design improvements were made to provide better cooling for AGP and PCI cards.***

***Keywords:*** *Forced cooling of the heat sink, CPU, Computational fluid dynamics*

## 1. INTRODUCTION

All electronic equipment relies on the flow of and control of electrical current to perform a variety of functions. Whenever electrical current flows through a resistive element, the heat is generated. Regarding the appropriate operation of the electronics, heat dissipation is one of the most critical aspects to be considered when designing an electronic box. Heat generation is an irreversible process and heat must be removed in order to maintain the continuous operation. With various degrees of sensitivity, the reliability and the performance of all electronic devices are temperature dependent. Generally the lower the temperature and the change of temperature with respect to time, the better they are. Pure conduction, natural convection or radiation cool the components to some extend whereas today's electronic devices need more powerful and complicated systems to cope with the heat. Therefore new heat sinks with larger extended surfaces highly conductive materials and more coolant flow are keys to reducing the hot spots. The performance criterion of heat sinks is the thermal resistance, which is expressed as the temperature difference between the electronic components and ambient per watts of heat load. It is expressed with units K/W. Today's electronic chips dissipate approximately 70 W maximum whereas this number will be multiples in the near future. The temperature differences from the heat sink surface to the ambient range from 10 ºC to 35 ºC according to the heat removal capability of the installed heat sink. For this study, the shape and size of the heat sink are modified so as to attain the maximum heat dissipation. In another design, a copper base plate is also introduced between the hot chip and the heat sink to improve the heat conduction paragraphs. Some content related to your research work in running paragraphs. Some content related to your research work in running paragraphs. Some content related to your research work in running paragraphs. Some content related to your research work in running paragraphs. Some content related to your research work in running paragraphs. Some content related to your research work in running paragraphs.

## 2. THERMAL INTERFACE MATERIALS

Once the heat sink and the fan, i.e., the cooling assembly is designed, a proper material should be selected to join the heat sink and the semiconductor, i.e. the heat source. There are various thermal interface materials serving this purpose. Although they seem as additional thermal resistances to heat flow, they form thin layers with high thermal conductivities and minimize the contact discontinuities.

All solid surface no matter how smooth they have certain roughness. Therefore when two surfaces come into physical contact, less than 1 % of the surfaces touch each other. The remaining area is filled with air, which is a poor medium for heat transfer. Therefore a more conductive material should replace the air. Thermal greases, thermal compounds, elastomers or adhesive films may be used as thermal interface materials. The table below shows the thermal resistances of these materials when used to join a Pentium test chip and a Wakefield pin fin heat sink. Yovanovich *et al.* present correlation equations to calculate interface resistances for conforming rough surfaces.

**Table 1: Thermal resistances of dry joint a thermal Interface materials**

| Interface | Thermal conductivity (W m.K) | Thermal resistance (K/W) |
|---|---|---|
| Dry joint | N/A | 2.9 |
| Thermal grease | 0.7 | 0.9 |
| Thermal compound | 1.2 | 0.8 |
| Elastomer | 5.0 | 1.8 |
| Adhesive Film | 0.7 | 2.7 |

Although thermal grease and thermal compound have very improved thermal resistances, the other two may also be preferred. Elastomers are typically used for devices where electrical isolation is required. The advantage of adhesive films is that they do not require any mechanical support like spring clips to attach a heat sink to the CPU.

## 3. COOLING METHODS IN CPU

Heat sinks may be categorized into five main groups according to the cooling mechanism employed:

- Passive heat sinks which are used generally in natural convection systems,
- Semi-active heat sinks which leverage off existing fans in the system,
- Active heat sinks employing designated fans for forced convection system,
- Liquid cooled cold plates employing tubes in block design or milled passages in brazed assemblies for the use of pumped water, oil or other liquids, and
- Phase change recirculating systems including two-phase systems that employ a set of boiler and condenser in a passive, self-driven mechanism.

In this study, active heat sinks to cool central processing units (CPUs) of desktop computers are investigated using CFD (Computational Fluid Dynamics).

## 4. PHYSICAL CONCEPTS

Computer chassis is the computational domain. Figure 1 shows the components of the chassis. It is a 3D chassis. CPU, CPU heat sink, Main Processor fan, North bridge chip, North bridge heat sink, South Bridge, South bridge heat sink, main board, memory cards, DVD- Rom, HDD (Hard Disk Drive), SMPS (Switch Mode Power Supply), exhaust fans and Inlet ports are shown on the figure.

The geometric details are dense around the CPU heat sink so a closer view is shown in the Figure 1. Since the scope of this study is investigation of temperature distributions on CPU heat sinks, closer view of one of the CPU heat sinks that is investigated in this study.

## 5. CFD CODE WORK

CFD codes are structured around numerical algorithms that can tackle fluid flow problems. In order to provide easy access to their solving power all commercial CFD packages include sophisticated user interfaces to input problem parameters and to examine the results. CFD codes contain three main elements.

- Pre-processor
- Solver
- Post processor

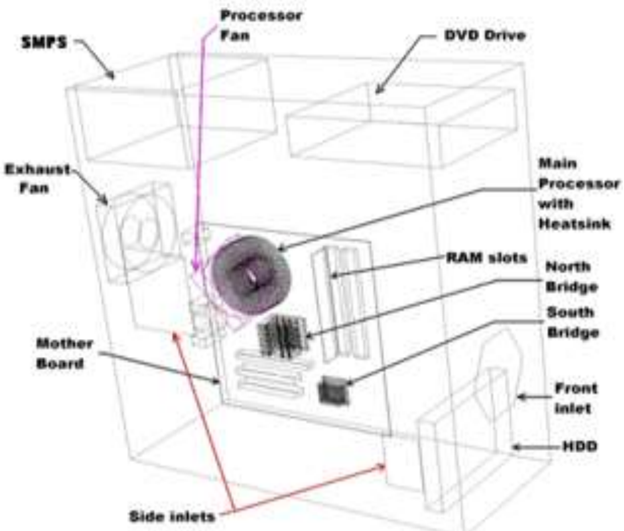


Fig 5.1

**Fig 1: Physical concepts**

### 5.1 Pre – Processor

Pre-processing consists of the input of a flow problem to a CFD program by means of an operator- friendly interface and the subsequent transformation of this input into a form suitable for use by the solver. The pre-processing stage involve:

- Definition of the geometry of the region of interest; the computational domain.
- Grid generation – the sub- domains into a number of smaller, non- overlapping sub-domains: a grid of cells.
- Selection of the physical and chemical phenomena that need to be modeled.
- Definition of fluid properties.
- Specification of appropriate boundary conditions at cells, which coincide with or touch the domain boundary.

### 5.2 Solver

There are three distinct streams of numerical solution techniques; finite difference, finite element and spectral methods. In outline the numerical methods that from the basis of the following steps;

- Appropriate of the unknown flow variables by means of simple functions.
- Discretisation by substitution of the approximation into the governing flow equations and subsequent mathematical manipulations.
- Solution of the algebraic equations.

The main difference between the three separate streams are associated with the in which the flow variables are approximated and with the Discretisation processes.

### 5.3 Post Processor

As in pre-processing a huge amount of development work has recently taken place in the post-processing field. Owing to the increased popularity of engineering workstations, many of which have outstanding graphics capabilities, the leading CFD packages are equipped with versatile data visualization tools. These include

- Domain geometry and grid display
- Vectors plot
- Line and shaded contour plots
- 2D and 3D surface plots
- View manipulation
- Colour postscript output

 

## 6. CFD MODEL

As you can see the existing heat sink design, it is of rectangular curved fin type. The whole heat sink is made of aluminum. We have designed three different heat sink designs. Namely

- Alpha heat sink,
- Ever cooler heat sink &
- Cooler master heat sink.

### 6.1 Alpha Heat Sink:

In this design, we have introduced cylindrical pin fins in the middle of the existing design. By introducing the pin fin instead of the solid inside it is possible to increase the surface area which will lead to maximizing the heat dissipation. The pin fin inside is of 2MM diameter and 25MM in height. It is shown in the following figure.

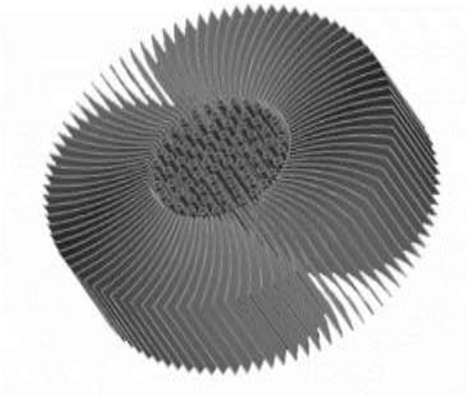

**Fig. 2: Alpha Heat Sink**

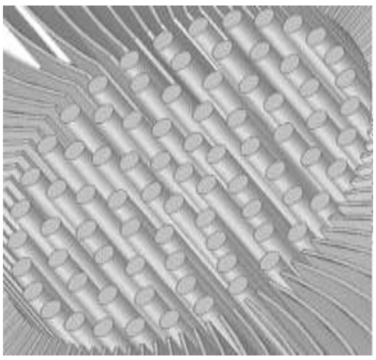

**Fig .3: Alpha H.S Closer View**

### 6.2 Ever Cooler Heat Sink:

In this design instead of the curved fin a rectangular fin with more gaps between each successive fin. This fin is made of 5MM thickness and 30MM height. The rectangular fins are arranged in such a way as to allow the air to pass through for the heat dissipation.

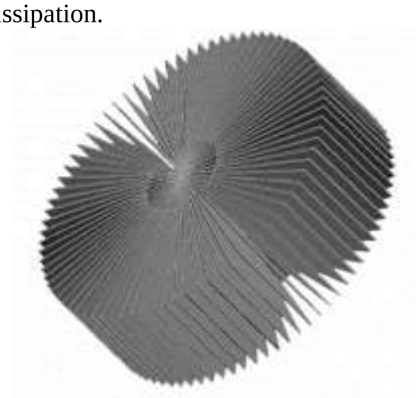

**Fig. 4: Ever Cooler Heat Sink**

### 6.3 Cooler Master Heat Sink:

It is similar to the previous model made up of the rectangular fins. But in this model, a copper base plate is introduced at the bottom of the heat sink. Since the copper is having the maximum thermal conductivity, the heat dissipation will surely increase. The copper base plate is of 5MM thick and 80MM in diameter.

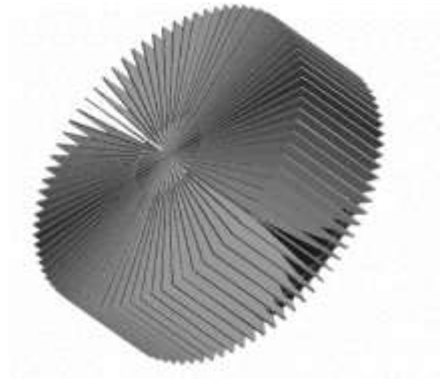

**Fig. 5: Cooler Master Heat Sink**

## 7. EXISTING HEAT SINK

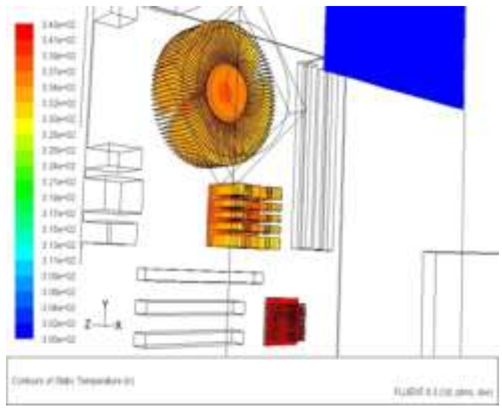

**Fig. 6: Temperature Distribution**

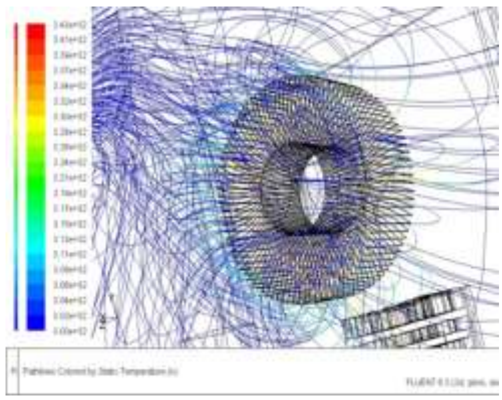

**Fig.7: Temperature Flow**

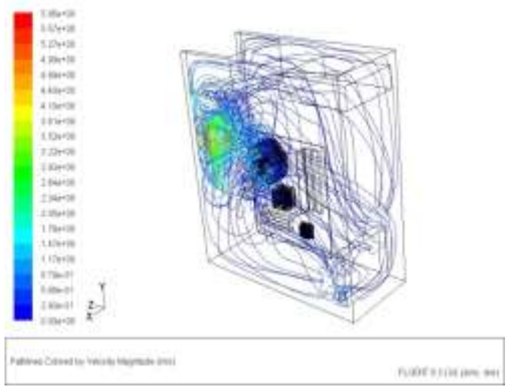

**Fig. 8: Velocity Magnitude**

 

**Mass flow rate at exhaust:**

```
Mass Flow Rate          (kg/s)
---------------------------------------------------
Exhaust             0.025542723
---------------------------------------------------
Net                 0.025542723
```

**Total heat transfer rate:**

```
Total Heat Transfer Rate          (w)
---------------------------------------------------
hot_chip1                    110.58664
hot_chip2                    52.945709
hot_chip3                    27.710808
Heat sink1                   93.588493
```

## 8. COOLER MASTER HEAT SINK

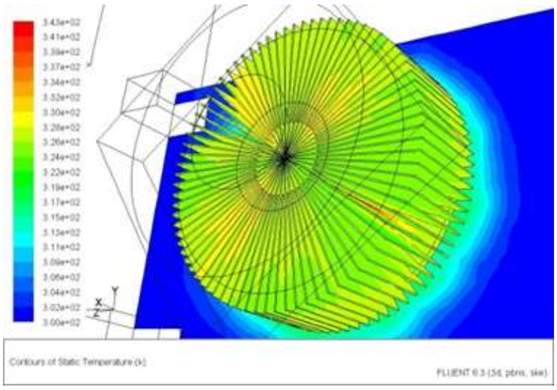

**Fig .9: Temperature Distribution**

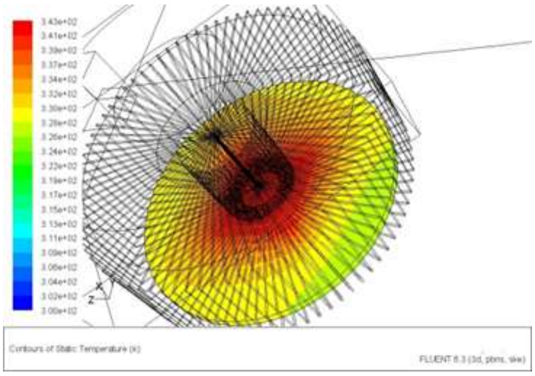

**Fig. 10: Temperature Distribution in Copper Base Plate**

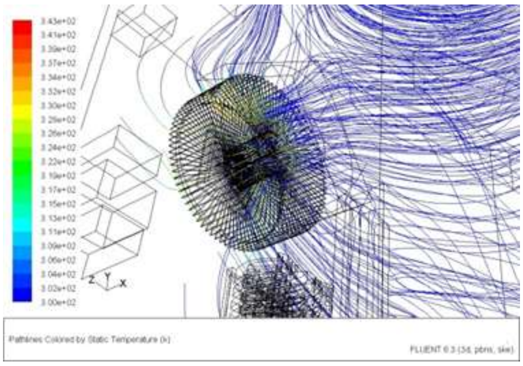

**Fig .11: Temperature Flow**

**Mass flow rate at exhaust:**

```
Mass Flow Rate          (kg/s)
---------------------------------------------------
Exhaust             0.022898293
---------------------------------------------------
Net                 0.022898293
```

**Total heat transfer rate:**

```
Total Heat Transfer Rate          (w)
---------------------------------------------------
hot_chip1                    131.70236
 hot_chip2                   61.454554
 hot_chip3                   28.771156
 Heat sink1                  97.758587+
Copper base                  12.547359
```

**Table-2: RESULT COMPARISONS**

| Heat sink type | Mass flow rate at exhaust (kg/s) | Total heat transfer rate (w) |
|---|---|---|
| Existing | 0.025542723 | 93.588493 |
| Cooler master | 0.022898293 | 110.305946 |

## 9. CONCLUSION

Improvements on heat sink designs are possible via CFD. Number of fins and their distribution, fin material and base plate thickness can be investigated and thermal enhancements may be succeeded as well as material saving. Successive parametric runs are necessary to be able to evaluate the effects of these design parameters. Eventually it is possible to end up with a new heat sink design which has better thermal performance and uses less material. In the current study, it was seen that stacking too many fins is not a solution for decreasing the hot spots on the heat sink since they may prevent the passage of air coming from the fan to the hottest center parts of the heat sink. If fin material is selected to be copper rather than aluminum, then the thermal resistance of the heat sink decreases as expectedly. However this makes the heat sink more expensive and heavier. The heat sink base thickness is also a parameter for improvement. In our cases, the footprint of the heat source is smaller than the width of the heat sink which introduces an in-plane conduction resistance. When the base plate thickness is increased the heat sink performed better, however there are space limitations for every heat sink in a computer. Therefore the total height of the heat sink should be considered together with the space limitations when increasing the height of the heat sink. Designing a narrower heat sink to decrease the in-plane conduction resistance is not a solution since it can accommodate fewer fins on itself which decreases the total heat transfer area. In this paper, the cooler master with copper base plate performs effectively in comparison with alpha & ever cooler heat sinks. This copper plate increases the direct conduction between the hot chip & heat sink. The total heat transfer rate increases by 17.8% i.e, 16.71 Watts when compared with the existing heat sink

## 10. REFERENCES


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