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Numerical analysis and modelling of optimized heat sink with parametric study and experimentation on current heat sink design for microprocessor

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ABSTRACT

This project mainly focus on increasing performance of existing plate fin by studying various parameters and modifying the design. For doing modifications we done experiment on existing heat sink by both force and free convection. Number of readings are taken through experiment to study the temperature distribution. After Experimentation calculations are perform and values of convective heat transfer coefficient (h), heat flow in terms of watt(W) from experimentation is calculated. This value are computed in the ANSYS software in Steady state thermal and numerical results are taken. Numerical results were validated with experiment result and good argument where observed. After successful study of existing design by both force and natural convection ,we move towards increasing the performance of heat sink. For this we done comparative study first in which we compare the base thickness, number of Notches, slots, optimum number of perforations, perfect position of perforation ,feasible shape of perforations etc. After all study and our observation we applied our study for modifying the heat sink design and we successfully modified the design which includes notches ,slots ,perforation where we got 5 degree of optimization compared to existing one.

Keyword - Heat Sink Optimization, Microprocessor Cooling, Perforated Fins, Thermal Analysis, ANSYS Simulation, Heat Transfer Enhancement, Fin Geometry

1. INTRODUCTION

With the rapid advancement of Information Technology, efficient thermal management has become critical for maintaining the performance and reliability of electronic devices, particularly microprocessors—the core of the Central Processing Unit (CPU). As electronic components generate heat during operation, effective heat dissipation is essential to prevent thermal damage and performance degradation.

Air cooling using heat sinks remains the most economical and reliable method for electronic cooling. This study focuses on enhancing the performance of plate fin heat sinks by exploring design modifications such as fin height, base thickness, and the use of perforations. Perforated fins offer increased surface area for heat transfer and potentially lower thermal resistance compared to solid fins.

Experimental and numerical analyses were conducted to evaluate the impact of these modifications on the heat transfer coefficient and temperature distribution using ANSYS under steady-state conditions. The goal is to propose an optimized heat sink design that improves thermal performance while minimizing material use and pressure drop.

2. LITERATURE SURVEY

Various studies have focused on improving heat sink performance. The IEEE [2](2001) found that pin fin heat sinks result in higher pressure drops at high Reynolds numbers with marginal thermal benefits. [4]Sachin and Demir (2008) showed that perforations in fins enhance heat transfer by increasing surface area and heat transfer coefficients. Mohan and Govindarajan[3] (2011) emphasized that CFD analysis can help optimize fin count, material, and base plate thickness for better thermal performance. Farhad Ismail [1]et al. (2013) reported that perforated fins outperform solid fins due to greater surface contact. A 2016 study revealed that triangular fins increase heat transfer by 9% over rectangular fins. Reddy[6] et al. (2017) concluded that increasing the number of fins and optimizing base plate thickness improves heat dissipation while reducing material use

3. OBJECTIVE AND PROBLEM STATEMENT

3.1 Objectives

1. To develop an optimized heat sink design with improved heat dissipation.
2. To ensure the new design is cost-effective and easy to manufacture.
3. To replace the existing heat sink with a simpler, more efficient version.
4. To perform a parametric study on factors like fin height, base plate thickness, and perforation patterns.

3.2 Problem Statement

Electronic components like microprocessors generate significant heat during operation, requiring efficient cooling to prevent failure. Current heat sink designs used in CPUs are complex, costly, and not thermally efficient enough. This project aims to redesign the heat sink to improve thermal performance and simplify manufacturing.

4. EXPERIMENTAL WORK

The experiment evaluates the heat sink's thermal performance and validates numerical simulation results. The setup includes a heater assembly consisting of an aluminum support channel, mica insulation, nicrome wire heating element, and asbestos insulation to minimize heat loss. A 15 V DC power supply powers the heater, while K-type thermocouples positioned at the top, middle, and base of the heat sink measure temperature variations. Airflow velocity over the fins is recorded using a hot wire anemometer. The collected data aids in analyzing heat dissipation efficiency and guides the optimization of heat sink design parameters.

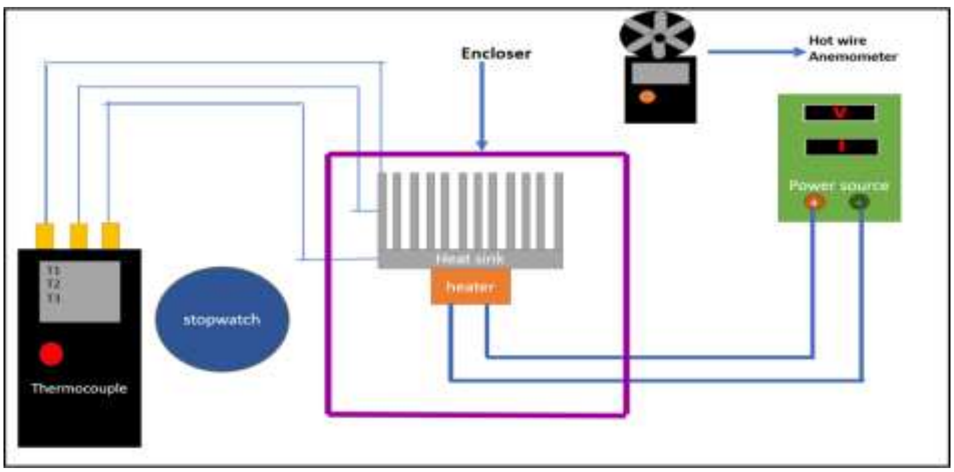

Fig 1 Experimental schematic

There are Two heat sinks under study:

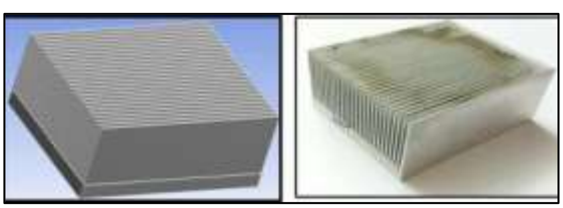

Fig 6 :- plate fin heat sink dimensions

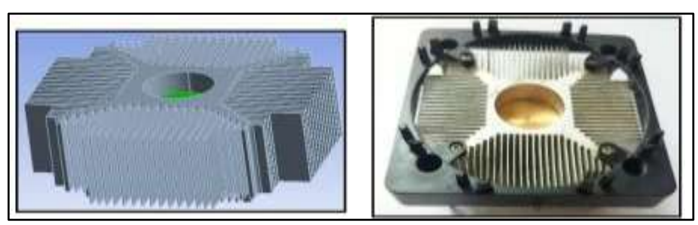

Fig 7:- Cross fin heat sink dimensions

4.EXPERIMENTAL STUDY

1. Natural convection - Convection is called natural convection when motion and mixing of fluid is caused by density variation resulting from temperature differences within the. Air/ fluid

Sr no	Voltage (volt)	Current (Amp)	Time (min)	T1 (Top)	T2 (Middle)	T3 (Bottom)
1	13	1.478	5	48	49.8	51.2
2	13	1.478	10	50.2	50.6	52.3
3	13	1.478	12	59.3	59.3	61.6
4	13	1.478	15	63.5	63.5	65.9
5	13	1.478	20	67.3	67.3	69.3

Table 1 :- Experimental Results of Plate fin heat Heat Sink by Natural Convection

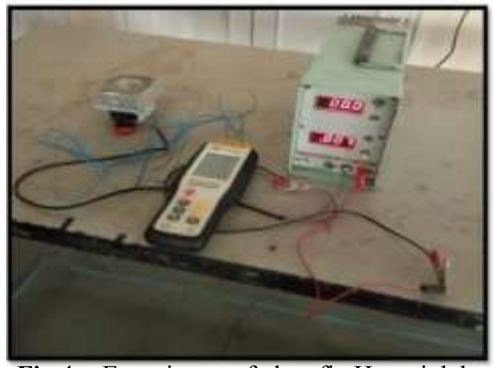

Fig 4 :- Experiment of plate fin Heat sink by Natural convection

2. Forced Convection – It is a mechanism or a type of transport in which fluid motion is generated by an external source (such as a pump, fan, suction device, etc

Table 2 :- Experimental Results of Plate fin heat sink by by Forced convection

Sr no	Voltage (volt)	Current (Amp)	Time (min)	T1 (Top)	T2 (Middle)	T3 (Bottom)
1	12	1.428	5	39.1	39.9	40.3
			10	39.3	39.4	40.6
			15	39.3	39.6	40.6
2	14.6	1.72	5	40.1	40.7	42.0
			10	40.3	40.7	42.1
			15	40.7	41.2	42.4

Fig 5 :-Experiment of Plate fin heat sink Forced Convection

5. CALCULATIONS

For analysis purpose the value of coefficient of convective heat transfer (h) is needed for finding the value of h we have perform the experiment on that basis value of h is calculated as follows:

Q = heat flow . A = area of heat sink

Q = I*V , Where I and V are current and voltage reading respectively

1)Natural convection –

$$Q = h \times A \times (\Delta T')$$

$$h = \frac{Q}{A\Delta T}$$

$$= \frac{19}{1334.64 \times 10^{-4} \times (64.3 - 34.47)}$$

$$h = 4.77 \ \frac{W}{m^2K}$$

2)Forced convection -

$$Q = h \times A \times (\Delta T')$$

$$h = \frac{Q}{A\Delta T}$$

$$= \frac{14.6 \times 1.72}{1334.64 \times 10^{-4} \times \left(\frac{(40.7+41.2+42.4)}{3} - \frac{(36.4+36.6+36.7)}{3}\right)}$$

$$h = 38.7 \ \frac{W}{m^2K}$$

7. MODELLING AND SIMULATION AND RESULTS using ANSYS Workbench

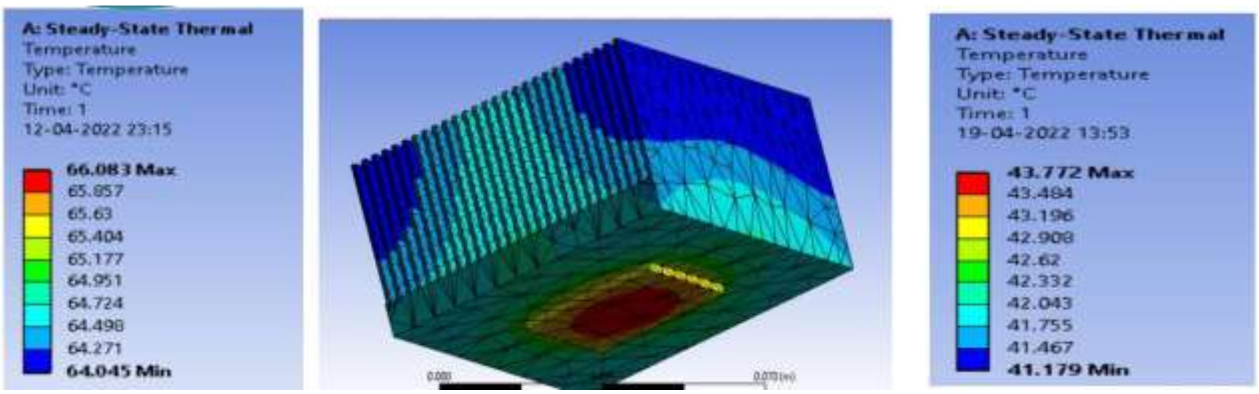

Fig 9 :- Analysis of plate fin heat sink under natural and forced convection conditions

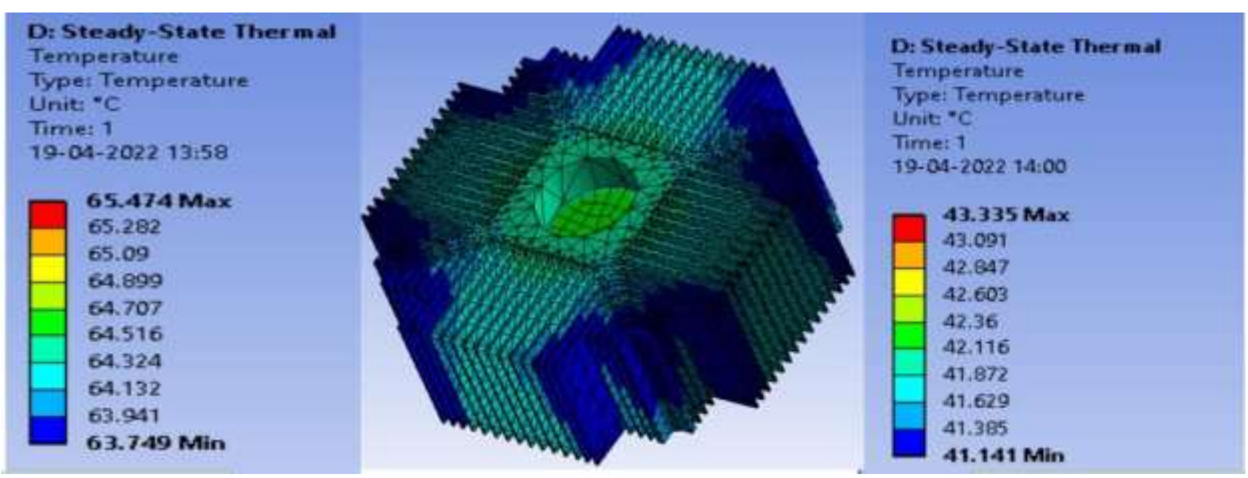

Fig 10 :- Analysis of cross fin heat sink under natural and forced convection conditions

8. COMPARATIVE STUDY

A comparative study was conducted by varying several geometric parameters to evaluate their effect on the thermal performance of heat sinks.

8.1 Key findings include

Parameter	Variable Studied	Observation (Effect on ΔT)	Conclusion
Copper Base Thickness	Increased thickness (mm)	ΔT increases	Better heat dissipation
Fin Height	Height up to 45 mm	ΔT increases up to a limit	Optimal height ≈ 45 mm
Perforation Diameter	Increased diameter (mm)	ΔT increases	Enhanced cooling with larger perforations
Number of Perforations	Increased count of 5 mm holes	ΔT increases	More perforations improve cooling
Perforation Offset from Center	Centered vs. offset	ΔT decreases with offset	Center perforation is more effective

9. OPTIMIZED HEAT SINK DESIGN

The heat transfer through heatsink take place through both conduction and convection processes. For improving the heat transfer through heatsink it is important to know how the heat is flowing through it. Study of conduction and convection with respect to heatsink help to develop better design. For improving conduction a material with better thermal conductivity should be used. For increasing heat transfer through natural convection the surface area need to be increased. And in case of forced convection the pressure drop across the should be as minimum as possible for better air flow. For improving the heat transfer performance of heat sink its design needs to be modified existing plate fin heatsink . For modification purpose various parameters have been considered which include perforation size, perforation shape, number of perforations, height of fin, thickness of copper base plate, notches of different shapes and sizes, slots in the fins etc. Analysis of various designs have been done. The designs which show better heat transfer performance are considered as modified designs. For analysis purpose of modified heatsink, same boundary conditions were given as that of existing plate fin heatsink. It was observed that heat transfer performance increases if relevant changes are done in the design.

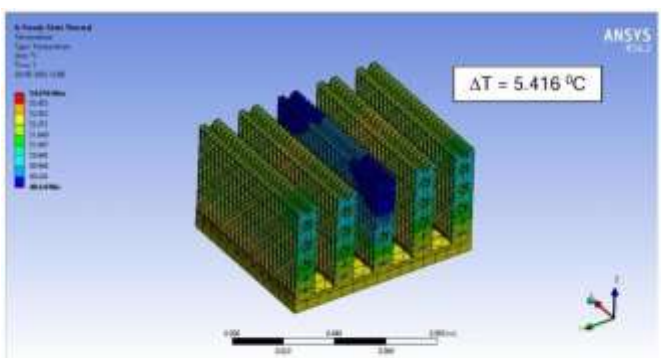

Fig 11 :- Optimized Heat sink design final which give maximum heat dissipation (Analysis Done by ANSYS)

This design is optimized by adding copper base plate, circular perforation and rectangular slots. It shows better results at the same boundary conditions as that of existing plate fin heat sink as the value of ΔT is larger. In this way by adding all the studied parameters the design is optimized. Dimensions Perforation diameter = 5mm Fin height = 35mm Base plate thickness = 4mm Copper base plate thickness = 5mm Rectangular slot=35 mm* 9.2 mm

10. CONCLUSION

This study investigates microprocessor cooling within an actual CPU chassis using two heat sink designs: plate fin and cross fin. Experimental results were validated with ANSYS simulations, which aligned closely with prior research, showing only minor errors. Both heat sinks demonstrated similar temperature differences and performance under natural convection. Various parameters—including fin number, temperature distribution, material, base plate thickness, fin height, and perforation size/shape—were analyzed for improving heat dissipation. Perforated fins showed higher effective surface area and better cooling than solid fins. Adding a base plate improved heat conduction more effectively than increasing fin height. Optimization focused on maximizing heat dissipation while minimizing pressure drop from perforations and slots. Loosely spaced fins enhanced airflow, improving cooling of the heat sink's hottest regions.

11. FUTURE SCOPE

Every machine or equipment has scope for advancement. Our model can be also improver to achive the better . The areas are listed below where implementation can be done. Alternate composite material or Improved conductivity material for Heat sink can be selected so that the overall performance of heat sink can be increased and weight of heat sink is reduced. Improvement in heat transfer coefficient h can be increase for Optimization. This improvement can be done by, 1. Increasing airflow velocity 2. Cross cutting of flat fins 3. Higher performance fans 4. Increase Exposed cooling surface area 5. Heat pipe 6. Liquid cooling 7. Oriantation of fan place on the heat sink.

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