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Efficiency comparison of fin heatsink models using Solidworks thermal analysis

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Abstract: Heatsink is composed of square or circular-shaped base plates connected to fins on one side. Fluid flow within the heatsink typically occurs through natural convection, where colder air flows into the hotter fin region and exits through the fin tips. In this study, we conducted numerical simulations using Solidworks 2021-2022 Research Licence software to investigate three different heatsink models with distinct shapes, aiming to determine the most effective cooling rate. The thermal simulation results revealed that the heatsink design with square fins exhibited lower maximum temperatures, making it recommended for applications utilizing natural convection. Additionally, heat sinks with thinner fins have a larger surface area, accommodating more fins compared to thicker ones, which affects the heat transfer efficiency within the heat sink.

Keywords: Heat sink; Solidwork thermal analysis; Thermal pad; Heat exchanger

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1. Introduction

The use of electronic devices has become a necessity for humans in this era. The high level of activity demands engineers to create a tool to facilitate these human activities. Electronic devices such as mobile phones, computers, and laptops have become indispensable tools in human activities. Since the invention of these devices until now, the development of electronic devices has never stopped. Thermal management in electronic devices has become the focus of researchers at present. The high temperature levels resulting from the operation of electronic devices themselves can cause a decrease in the performance of these devices (Rostami et al., 2022). Most chips experience high temperatures, therefore cooling is necessary to reduce the temperature optimally (Nabi et al., 2023). Therefore, a heat exchanger is a vital component in an electronic device that can maintain the optimum temperature of the device (Hou et al., 2011).

There were two fundamental phenomena that occurred in the heat exchanger: fluid flow within the component and heat transfer between the fluid and the walls of the electronic component (Dhaiban & Hussein, 2020). The heat transfer coefficient depended greatly on the ratio of surface area to volume, meaning that smaller dimensions of electronic components provided better heat transfer coefficients (Alawwa et al., 2023). That's why there have been many studies on heat exchangers that utilize electronic components (Hai et al., 2023). To maintain good performance of electronic components, there are three ways in which temperature can be reduced. Firstly, by limiting heat generation within the components without sacrificing performance. Secondly, by adopting efficient thermal heatsinks. Thirdly, by reducing the thermal resistance of the system (Ringe et al., 2015). In this discussion, the second method will be chosen, which is the heat dissipation process using a heatsink, and the effectiveness of the heatsink depends on its type. The type of heatsink commonly used is the Extruded heatsink (Wang & Hai, 2023)

This study aims to uncover the characteristics of a heatsink that has been designed using the Finite Element Analysis (FEA) method. The Finite Element Method, also known as Finite Element Analysis, is an approach to solving engineering problems by dividing the analyzed object into small, finite-sized elements (Lee, 2010). These small elements are then analyzed, and their results are combined to obtain a solution for the entire area (Toprak et al., 2022).

2. Methods

Software used in the Finite Element Analysis (FEA) method for this study was the Solidworks 2021-2022 Research License. FEA can be utilized to analyze specific engineering issues, such as structural strength, corrosion, heat transfer, and combined loads. For instance, a partially corroded structure with varying thickness in different areas cannot be analytically calculated. However, with the discretization process in FEA, it can be easily resolved (Toprak et al., 2022)

2.1 Design of heatsink fins

There were three heatsink design models created. Model 1 (Figure 3.a) was designed in a square shape along the platform (60 mm) with a thickness of 5 mm, a height of 40 mm, and a distance of 4 mm between the fins. Model 2 (Figure 3.b) was designed with a reduced thickness at the top (2 mm). The length, height, and distance between fins in Model 2 were the same as in Model 1. Model 3 (Figure 3.c) was designed in a cylindrical rod shape with a diameter of 4 mm and a distance of 4 mm between the rods.

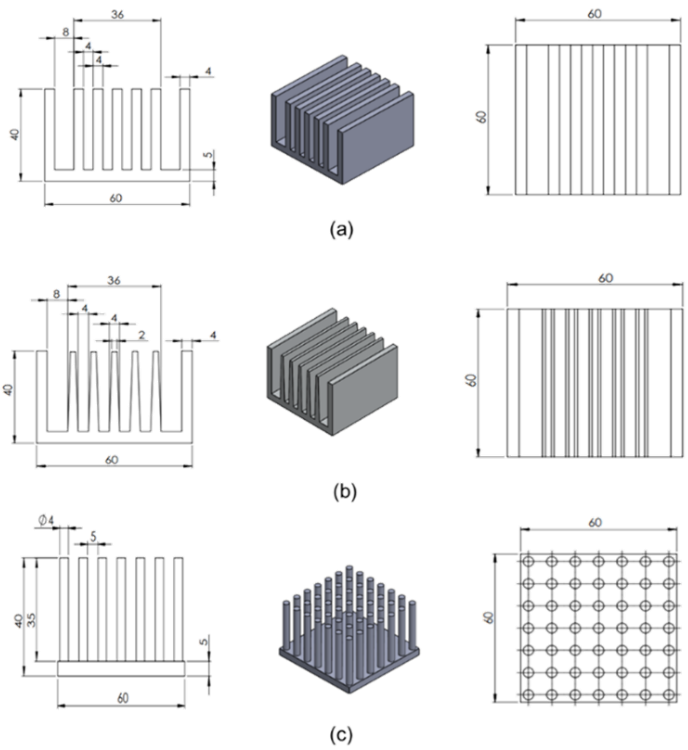


Figure 1. Heatsink (a) Square, (b) Trapezoid and (c) Rod

2.2 Thermal pad (prosesor)

In this analysis, the component used is a computer processor, which utilizes copper material with dimensions of 40 mm in side length and 5 mm in thickness. The thermal pad plays a role as a component that generates heat in this analysis. The thermal pad will be attached to the underside of the designed heatsink and subjected to a heat power of 40 Watts.

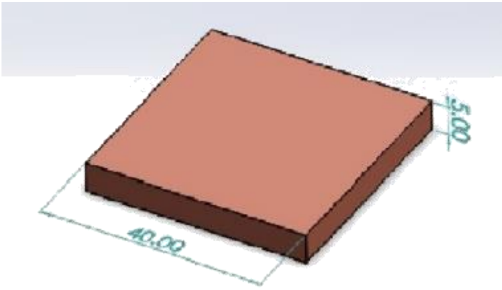


Figure 2. Thermal pad (chip prosesor)

2.3 The research variable

The research variables are the aspects that receive attention, exert influence, and possess a value. Variables are quantities that can be altered or changed, thereby influencing events or research outcomes. The determined variables are the control variable, independent variable, and dependent variable. The control variable is a variable that remains constant throughout the research. The independent variable is a variable that is deliberately varied or manipulated in the research. The dependent variable is the variable being observed or measured. The control variable is kept the same across the research. The convection coefficient and heat power used are based on references from previous studies on processor heatsinks that already exist..

- The control variable

Convection Coefficient	: 30 W/(m^2.K)
Heat Power	: 40 W
Heatsink size	: 60 mm x 60 mm x 5 mm

- Independent variable:

  Rectanguar
  Trapezoid
  Rod

- Dependent variable:

  Heatsink maximum temperature
  Heatsink minimum temperature

2.4 Heatsink and thermal pad materials

The material of the above heat transfer case is as written in Table 1.

Table 1. Material properties

Specification	Heatsink	Thermal pad
Material	Aluminium 6063-O	Copper
Specific Heat	900 J/(Kg.k)	385 J/(Kg.k)
Heat Conductivity	218 W/(m.k)	386 W/(m.k)
Density	2700 kg/m^3	8900 Kg/m^3

2.5 Meshing

The "create mesh" feature was used to determine the number of nodes, number of elements, and element sizes in the square heatsink model. The mesh results for the heatsink design showed data with solid mesh elements. The obtained element size was 4.39475 mm, with a tolerance of 0.21973, and there were 21,436 nodes and 12,369 elements.

2.6 Mesh Independence Test

The mesh independence test is conducted to ensure that the simulation can proceed with the optimization process by determining an appropriate number of elements. This is done by using the "control mesh" menu and gradually reducing the mesh size. The optimal result was obtained with a mesh size of 4 mm. The Mesh Independence Test results are presented in Table 2 and the corresponding graph in Figure 3.

Table 2. Mesh independence test

Mesh size (mm)	Max Temperature(ºC)	Number of element
5	60,630	8.927
4	60,644	12.274
3	60,643	27.121
2	60,650	79.139

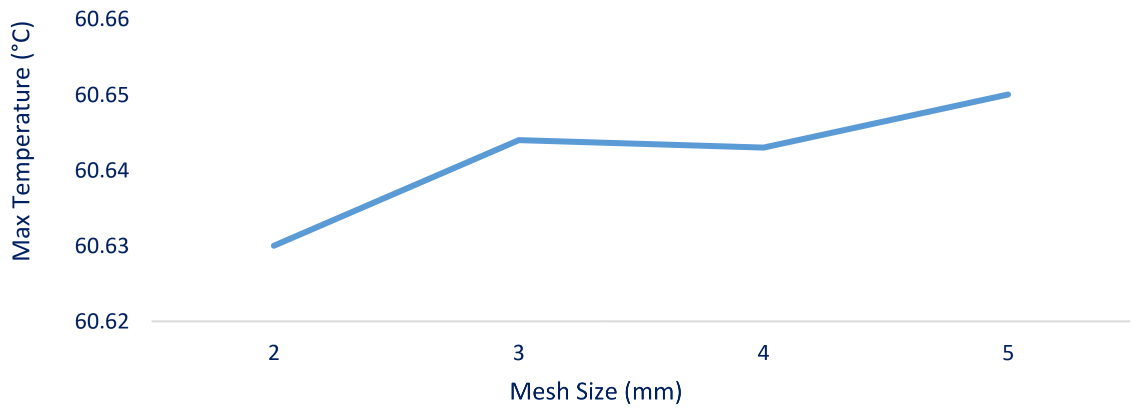


Figure 3. Mesh independence test

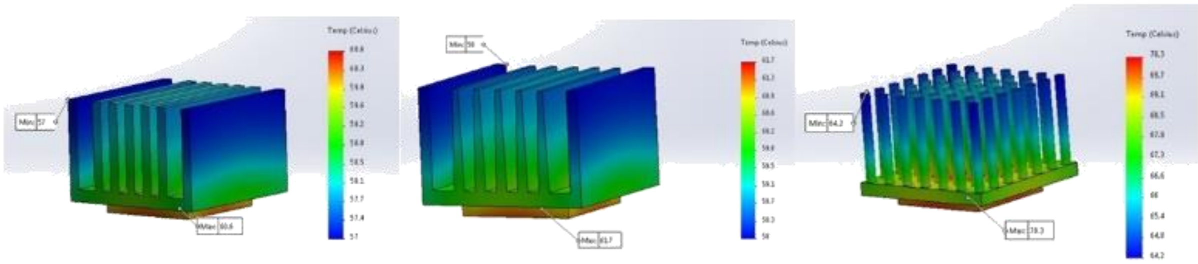
2.7 Equation of heat transfer

Convective heat transfer is calculated by multiplying the convective heat transfer coefficient (h) with the surface area (A) and the temperature difference (ΔT). The result is the amount of heat transferred through convection from the object's surface to the surrounding fluid (equation 1).

$$H = h \,.\, A \,.\, \Delta T \tag{1}$$

3. Results and discussion

There are three heatsink models analyzed based on their cooling fin shapes, namely trapezoid, square, and rod. The heat transfer process from the heatsink to the air can be categorized as free convection, where the air flows naturally without any external forced energy in the system.



(a) (b) (c)

Figure 4. Results of thermal analysis on the heatsink (a. Square, b. Trapezoid, c. rod)

The figure displays the distribution of heat generated by the electronic component (processor chip). In Figure 4(a), the highest temperature is observed on the rectangular fin heatsink with a convection coefficient of 30 W/(m2.K), reaching 60.644 °C. In Figure 4(b), the trapezoid fin heatsink reaches a maximum temperature of 61.705 °C. Based on the recommended temperature for the processor component, which is around 60°C, both the square and trapezoid fin models can be used in the designed heat sink. Generally, it is known that 60°C is the standard that should represent the ideal temperature. If the CPU temperature is below 60°C, then the component will work optimally. However, in Figure 4(c), the rod fin heatsink reaches a maximum temperature of 70.332 °C. It can be concluded that the heatsink with this design is less efficient to use in designing a heatsink because the performance of the processor component decreases due to the component's temperature exceeding the recommended limit.

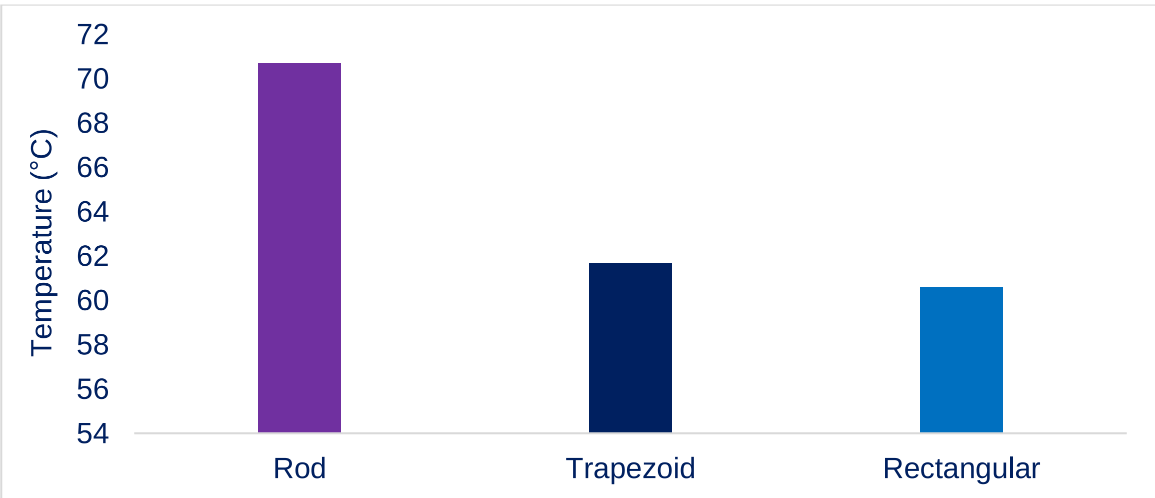


Figure 5. Graph of temperature differences in each form of fins

In Table 3, it can be observed that the highest temperature differs for each heatsink fin design model. From the analysis of the data, it is evident that the rectangular fin heatsink model performs better in reducing the temperature of the electronic component. This can be attributed to the larger surface area or contact area of the rectangular heatsink, which significantly influences the efficiency of the heatsink in accelerating heat dissipation from the component. The rectangular heatsink has a larger surface area compared to the other two fin models.

Table 3. Effect of fin shape on maximum temperature

Fin Shape	Surface area (mm^2)	Convection Coefficient $W/(m^2.K)$	Heat Power (W)	Maximum temperature °C
Rectangular	39760	30	40	60,644
Trapezoid	38634	30	40	61,705
Rod	29951	30	40	70,332

To enhance the convective heat transfer coefficient, variations in geometry, position, velocity, and flow direction of the fluid can be implemented (Nabi et al., 2023). This corresponds to the convective heat transfer rate, which depends on the fluid and surface temperature, velocity of the flow around the surface, and the surface area in contact with the fluid. A higher convective coefficient results in a lower maximum temperature achievable by the component, implying a decrease in component temperature (Rostami et al., 2023). Furthermore, an increased fluid contact area with the heatsink surface leads to an augmented convective heat transfer rate. Additionally, the utilization of alternative materials such as copper, brass, and others can also be analyzed through diversified modeling techniques.

4. Conclusion

The efficiency of a heatsink depends on several factors, including the surface area that can be increased by adding more fins, the convective coefficient value, and the material selection for heatsink design. By increasing the number of fins, the surface area in direct contact with the fluid (air) also increases proportionally. It is expected that the results of this analysis can serve as a foundation for the development of more efficient heat sinks in the future, with more effective fin designs and optimal material selection for the heat sink.

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Declarations

Author contribution

Angga Hermawansyah makes significant contributions by crafting designs, simulating, analyzing data, processing information, and authoring articles. Meanwhile, Andre Kurniawan, Sein Lae Yi Win and Nanang Qosim actively participate in scrutinizing and interpreting the research findings. Syamsul Bahri Biki and Apri Wiyono play crucial roles in crafting compelling articles, revising them, and ensuring meticulous proofreading.

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Conflict of interest

The authors declare no conflict of interest.

Ethical Clerance

There are no human subjects in this manuscript and informed consent is not applicable.

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