THERMAL ANALYSIS OF FLAT PLATE HEAT SINK WITH FINS OF DIFFERENT CONFIGURATIONS UNDER NATURAL CONVECTION

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Abstract:

This paper investigated the effect of four different configuration of plate fin heat sink subjected to natural convection. Comprehensive thermal performance was studied for each of the heat sinks. The test 1 heat sinks is the normal or control heat sink, test 2, heat sink have its fins tapered and fillet, test 3 has its fins only tapered, while test 4, has its fins filleted. Investigations were performed for variables such as 100W heat source, 303 K ambient temperature and convective coefficient of air 25 W/m^2 K. a temperature color map of the heat sinks were plotted and also, the temperature profile of the center fin for each heat sink. The results show that test 4 has a 11.89% than the other three test 1 configurations.

Keywords: Heat sink, fillet, tapered, temperature, cooling.

1.0 INTRODUCTION

Heat sink is an electronic component or a device of an electronic circuit which disperses heat from other components (mainly from the power transistors) of a circuit into the surrounding medium and cools them for improving their performance, reliability and also avoids the premature failure of the components. For the cooling purpose, it incorporates a fan or cooling device mostly made from Aluminum alloy such as the one used in (Raaid, 2013)**.**

Extended surfaces or fins are commonly found on electronic components ranging from power supplies to transformers. The dissipation and subsequent rejection of potentially destructive self-produced heat is an important aspect of electronic equipment design. The dissipation of heat is necessary for its proper function and component life, (Sandhya & Kishore, 2015). The heat is generated by the resistance encountered by electric current(Sampath, Sawan, & Chithirai, 2015). Many electronics components require proper cooling arrangement during design stage, the operating temperature most exceeds permissible limit, mostly specify in the component datasheet.

2.0 Literature Review

(Zhipeng, Xianghui, Liangbin, & Mengqiao, 2020)presents an effective method for predicting and optimizing the cooling performance of Parallel-Plain Fin (PPF) heat sink module based on the Taguchi method. The numerical simulative analyses of the PPF heat sink module have been constructed to understand the affecting situation of its related modeling parameters. The design parameters evaluated are the outline design of the heat sink module and the wind capacity of fan, and the highest temperature (or thermal resistance) of this module is considered as the performance characteristics. Taguchi method for the design of experiment (DOE) and the analysis of variance (ANOVA) are applied to find the optimized design parameters efficiently. From the numerical simulative analyses, the optimum design parameters to obtain the lowest value of the highest temperature (or thermal resistance) are found, and the highest temperature value has decreased to 8.009 °C and about 15.01% improvement. The result of the analyses of the noise factors has shown that the two noticeable variable factors are the wind capacity of the electric fan and the gap of fin flake. By using Taguchi method for design of experiment (DOE) and the analysis of variance (ANOVA), four noticeable variable factors will be obtained: number of opening slot, copper base surface area, wind capacity of the fan, and the height of the fin flake respectively.

(Arularasan, 2008)have selected an optimal heat sink design in their research work, preliminary studies on the fluid flow and heat transfer characteristics of a parallel plate heat sink have been carried through CFD modeling and simulations. The geometric parameters fin height, fin thickness and fin pitch have been considered in this work. In this research work, optimal design of the heat sink is carried out on a parallel plate heat sink using CFD study. Experimental studies have been performed with a parallel plate heat sink to validate the heat sink model. These results and conclusions drawn in this paper benefit the design engineers involved in electronics cooling.

Kim et al. (2008) have compared the thermal performances of the two types of heat sinks most commonly used in the electronic equipment cooling: plate-fin and pin-fin heat sinks. In order to obtain the fluid flow and thermal characteristics of heat sinks, an experimental investigation is conducted. Based on the experimental results of the present study and the available data from the existing literature, the correlations of the friction factor and the Nusselt number are suggested for each type of heat sink.

Heat sinks with parallel arrangement of rectangular cross section plate fins on a flat base are used preferably in vertical or upward facing horizontal orientations in order to obtain higher natural convection rates (Tari, 2013).

In practice, there is certainly a need for investigating the relationship between the heat sink design variable for easy and effective performance, as there are thousands of applications for heat sinks that require unique configuration, as while was suggested as a viable solution for cooling of flat panel displays with high power components (Tari, 2013). There are several that have been conducted on natural convection heat transfer from flat plate heat sinks (Mittelmann et al. [1]) and Starner and McManus [2]

3.0 Materials and Method

3.1 **Numerical computation**

In this section, the investigation develops a CFD model to analyze the effect of tapered and fillet profile on the convective heat transfer in plate-fin heat sinks. There are three main steps in CFD analysis: (a) pre-processing, (b) solver execution and (c) post-processing. The former step includes creating the geometry of the desired model as well as the mesh generation, whilst as expected, the results are presented in the last step. Boundary conditions are fed into the model in the solver execution (middle) stage.

3.2 **Geometry**

In this paper, four (4) sets geometries of the heat sinks were investigated. And their configurations are shown in figure 1. For the plate-fin heat sink with fillet profile, the optimum radius of fillet profile equal to 1.5 mm is considered for the remainder of paper as detailed in (Ammar, 2019). The base dimension measures 40 mm × 39.7 mm, with thickness of 5 mm. The channel width and thickness of fin is assumed to be constant across the length of the base and measures 3.3 mm and 1 mm respectively as shown in Fig. 1. The tapper angle is 3^{o}C. the fin height are between 25mm and 28.5mm. The difference is due to the compensation for the volume of solid material that removed from the base to generate fillet and tappered. For the remainder of paper, the plate-fin heat sink subject to the same thermal condition. Proposed design refers to as a plate-fin heat sink subject to parallel flow so that the air flows into the heat sink along the x-axis.

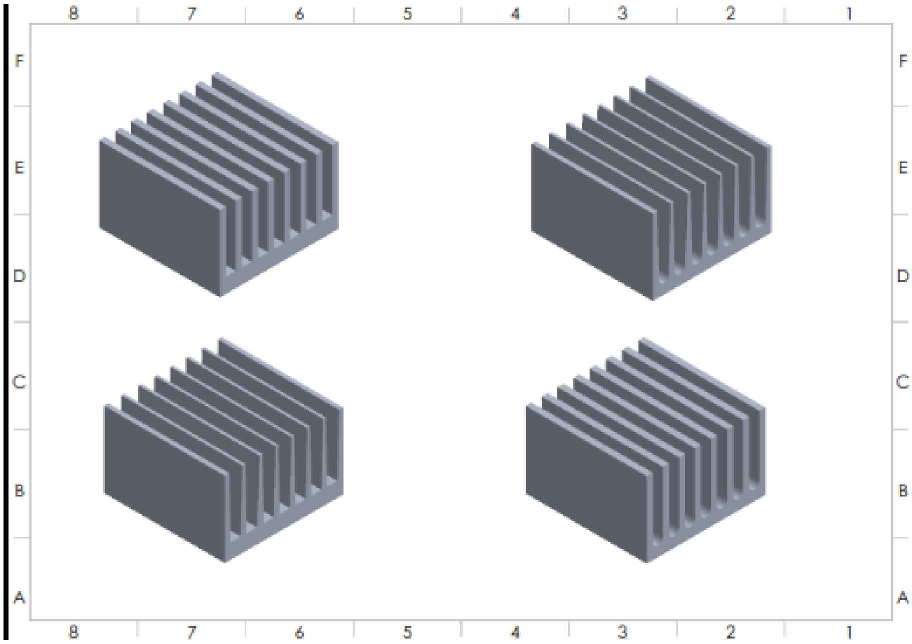


Fig. 1. The geometrical model (a) Conventional design and (b) Proposed designs.

3.3 Mesh generation

In this paper, mesh was generated using Solidworks 2019 software is used to construct the computational grid as well as to discretize and to solve the governing equations of mass and heat transfer. To ensure the accuracy of the simulations, the mesh needs to be generated with care in terms of computational time. To reduce the computation time, the mesh with lower elements were be used.

3.4 Boundary conditions

The boundary conditions of a simulation is similar to the work published by (Babarinde, Adeleke, Ogundeji, Adeyeye, & Ganiyu, 2014)where constant heat power of 150W, convective coefficient of air of 25 W/m^2-K. and an inlet variable value of inlet air flow (i.e. 0.00092, 0.00218, 0.0033 and 0.00433 kg/s) has been applied. the plate-fin heat sink is made from Aluminium alloy 6061. Electrical heaters warm the heat sink up and the temperature distribution at the base of the heat sink at different flow rates is measured by probe.

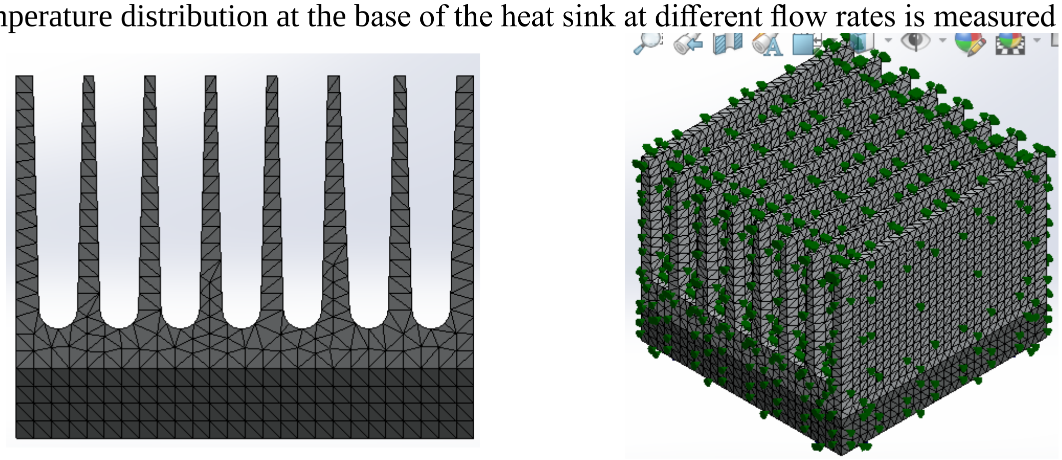


Figure 2: Meshed Geometry

3.5 Heat Sink Resistance Modeling

The primary aim of this research work is to determine the adequacy of the plate heat sink for small electronic coponents. the performance of heat sink is a function of its thermal resistance,(Mohsin & Kherde, 2015). One dimensional method were used to determine the equivalent resistance of the heat sink shown in figure 2shows the global resistance R, in the heat sink and present in equation 1.

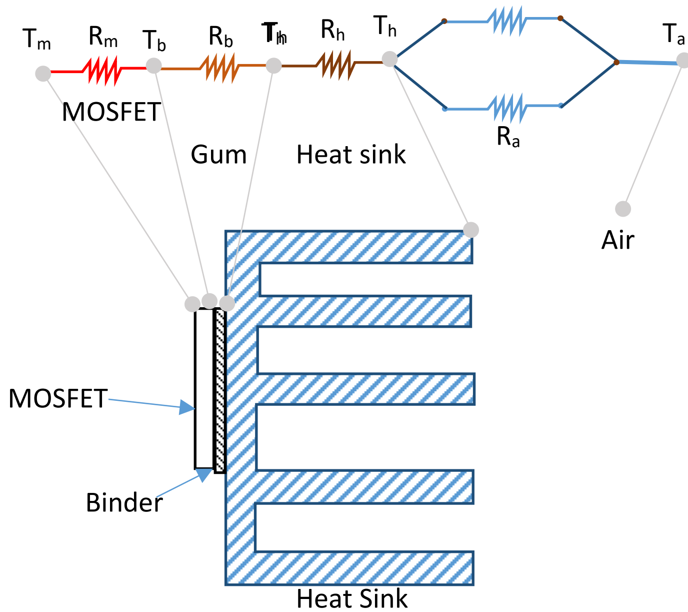


Figure 2: Heat Resistance Circuit.

$R= R_h+R_b+R_m$ 3.1

where

R_m is resistance of the MOSFET, R_b is Resistance of Binder, R_h is Resistance of the heat sink, Ra is Resistance of the air.

The R_h requires an extended analysis because the heat is dissipated to the environment through conduction, convection and radiation from the surface of the heat sink, as presented in figure 3.4

$R_h = R_c + R_v + R_r$ 3.2

And

$R_c = \frac{t_p}{k.A}$ 3.3

$R_v = \frac{1}{hA}$ 3.5

$R_r = \frac{1}{h_r.Ap}$ 3.6

And

$h_r = \varepsilon\sigma(T_h - T_\infty)(T_2^2 + T_\infty^2)$

Where;

$\varepsilon$is emissivity of the surface of the flat plate.

$\sigma = 5.67\alpha w^{-8}$ w/m^2.ic^4

K is plate thermal conductivity (W/k.m), A is heat transfeer area (m^2), t_p is thickness of the binder (m)

3.6 Fin Parameter (m)

Yunus (2008), noted that the fin parameter m of a annular fin of rectangular cross section is given by;

$$m = \sqrt{\frac{2h}{kt_f}} \quad 3.7$$

3.7 Fin Effectiveness(ε_f)

, noted that fins effectiveness is the ratio of the heat transfer from the finned surface to that of heat transfer from the same surface without fins. Yunus (2008), also noted that the fin effectiveness is calculated by;

$$\varepsilon_f = \sqrt{\frac{kP}{hA_c}} \quad 3.8$$

Where;

k is thermal Conductivity of the fin material (W/m.K), P is fins Perimeter (m), A_c is fins cross sectional area (m^2)

3.8 Fin Efficiency(η_f)

Fins design are not always likely to be too long so that their temperature does not approach the surrounding temperature at the tip of the fins (Yunus 2008). In order to improve heat dissipation rate of the brake drum; the temperature at the fin tip are considered not to approach the surrounding temperature.

Yunus (2008), relates fins effectiveness and fin efficiency as;

$$\varepsilon_f = \frac{A_f}{A_b}\eta_f \quad 3.9$$

$$\eta_f = \frac{A_b}{A_f}\varepsilon_f 3.10$$

Where A_f= Total Surface Area of the Fin

A_b= Base Area of the Fin

4.0 Results and Discussion of the results

The shape of a heat sink contribute to its performance and therefore, the results of the various heat sink configuration used in the research work are shown in Figure 4. Figure 4a, present the results for the normal or control heat sink. Figure 4b, shows the result of the heat sink that have its fin tappered and fillet. And figures 4c and 4d are results of the heat sinks with tappered and fillet fins respectively.

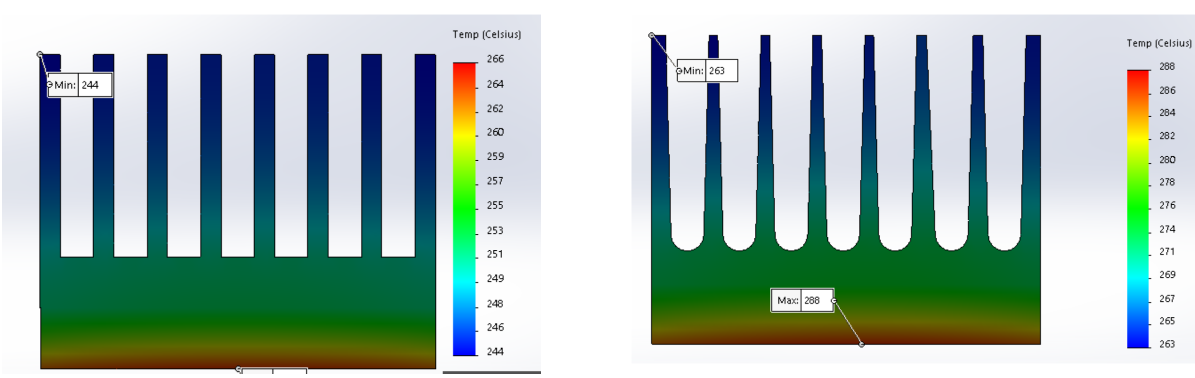
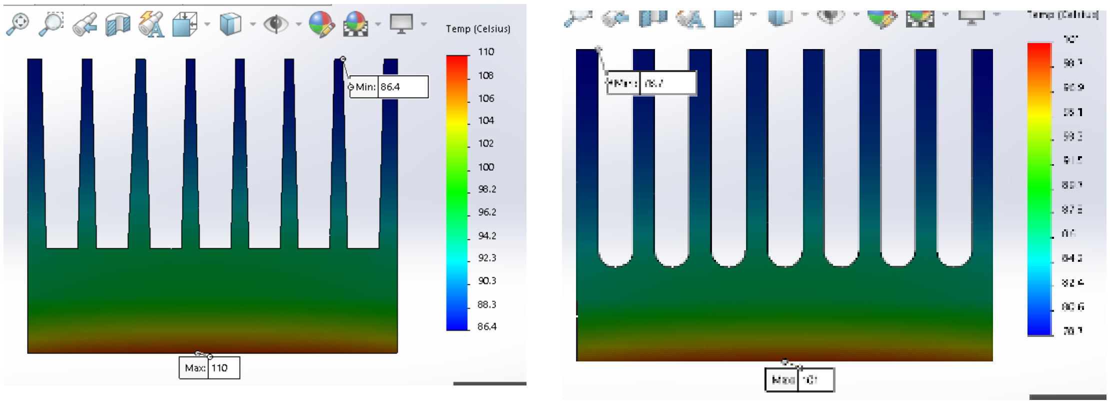


Figure 4: Temperature distribution of the Test 1 and Test 2 of the heat sink.

The minimum temperature for the configurations in Figure 4a, 4b, 4c and 4d are 244°C, 266 °C, 270 °C and 238 °C respectively, while the maximum temperatures in the heat sinks are °C, 266 °C, 288 °C, 294 °C and 260 °C respectively. From this results it is clear that under natural convection test 4 and Test 1 have a better performance, while test 2 and test 3 have a poorer performance. but test 4 has a better result that all other three heat sinks and it is cooler during operation. This explaination is also confirm on the graph shown in figure 5.



c – Test 3 d – Test 4

Figure 5: Temperature distribution of the Test 1 and Test 2 of the heat sink.

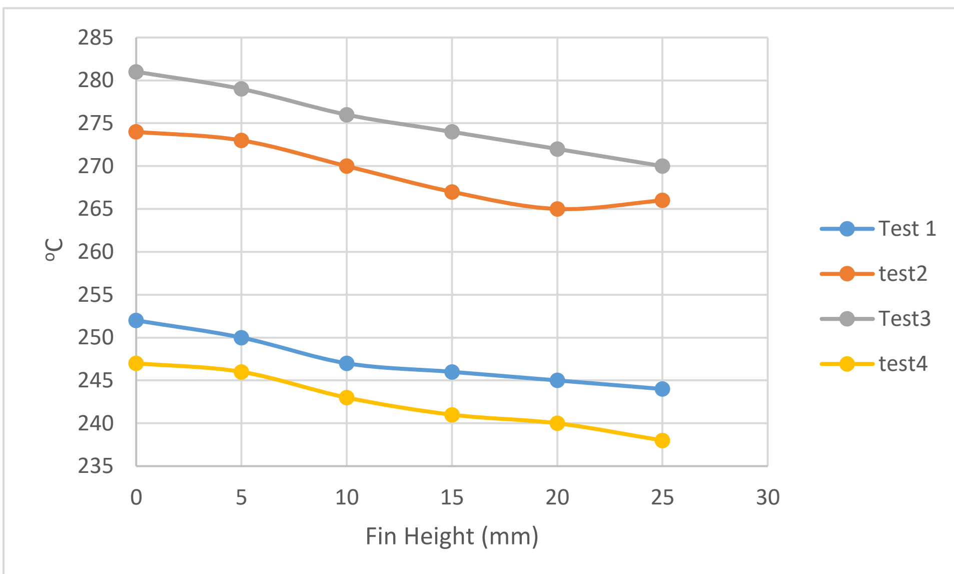


Figure 5: Comparison of the Temperature profile of the middle fin for each heat sink.

Conclusion

The objectives of this study has been successfully achieved by using CFD software. As temperature difference in the heat sink occur in different configurations of the flat plate heat sink used in the study. A 3D model of the heat sinks has been produced and a thermal simulation was conducted on each configuration of the heat sink. The results of the thermal analysis shows that the other of their performance is test 3, test 2, test 1 and test 4 respectively. Test 3 has the highest heat sink temperature of 294°C while test 4 has the lowest heat sink temperature of 238 °C.and this reveal that fillet has greater important on the heat sink cooling performance.

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