Thermal Analysis and design optimization of heat sink using taguchi method

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Abstract: Heat sinks are a kind of heat exchangers used for cooling the electronic devices due to the simplicity of fabrication, low cost, and reliability of heat dissipation. The objective of current research is to conduct thermal analysis of heat sink using FEA and to investigate the effect of individual design parameters on heat dissipation by generating contours of temperature and heat flux. The CAD model of heat sink is developed in ANSYS design modeler and design parameters are optimized using Taguchi response surface optimization technique. The critical range of values of each design parameters are determined for which heat flux and temperatures are minimum or maximum. The sensitivity plot is also determined for each design parameter which shows the percentage and effect of each variable for output variables (temperature and heat flux). From the optimization studies, the results have shown that the fin_base is the most significant variable for improving design of heat sink.

Key Words: Heat Sinks, Design optimization, thermal analysis

1. INTRODUCTION

Application of cooling system in thermal engineering is recognized and have been studied both theoretically and practically in building energy system, electronic devices, chemical vapor deposition instruments, solar energy collectors, furnace engineering, and many more. In recent years, thermal management of electronic devices is of interest as a new generation of high performing dense chip packages that function at high frequency produces a very high heat flux on the electronic devices. Prolonged heat flux creates a hot spot on the electronic devices and reduces the lifespan of the electronic devices because of the acceleration of the mean time to failure. Thermal management of compact electronic devices that operate at high power density is critical as there is a lack of efficient technique to remove heat dissipation from the electronic devices.

2. LITERATURE REVIEW

S.C. Fok et.al. [1] conducted an experimental study on the cooling of portable electronic devices using neicosane as a phase change material (PCM) placed inside heat sinks with and without internal fins. The effects of the PCM, the number of fins, the orientation of the device and the power level (3 to 5 W), on the transient thermal performance were studied under conditions of frequent and intense use. and light. The results indicated that PCM-based heat sinks with internal fins are viable options for cooling mobile devices, but the effectiveness of the approach may require optimization with respect to the amount of PCM used, the number of fins, the level power rating of the heat source and how the device is used.

Sidy Ndao et.al. [2] proposed a multi-objective thermal design optimization and a comparative study of electronic cooling technology. The cooling technologies considered are continuous parallel microchannel heat sinks, inline and offset circular fin heat sinks, offset band fin heat sinks, and single and multiple submerged jet. Using water and HFE-7000 as coolants, the functions of Matlab's multi-objective genetic algorithm were used to determine the optimal thermal design of each technology based on total thermal resistance and consumption. pumping energy with constant pressure drop and a base area of the heat source of 100 mm2. Pareto front graphs indicate a trade-off between total thermal resistance and pump energy consumption. Overall, the offset band fin heat sink outperforms other cooling technologies.

Dong-kwon kim et.al. [3] The proposed thermal optimization of a plate fin heat sink with variable fin thickness in the direction normal to fluid flow was performed. The model used for this optimization was based on the average volume theory. It has been shown that the thermal resistance of the plate-to-fin heat sink can be reduced by allowing the thickness of the fins to increase in the direction normal to fluid flow. In the case of a water-cooled heat sink, the thermal resistance decreases by up to 15%. The amount of reduction increases as the pump power increases or the length of the heat sink decreases.

Loannis K. Karathanassis et.al. [4] proposed. In this study, an optimization methodology is applied for a micro-channel, plate-fin heat sink suitable for cooling a linear parabolic system with photovoltaic / thermal concentration. Two different configurations of microchannels are considered, respectively fixed microchannels and steps of variable width. Performance evaluation criteria include the thermal resistance of the heatsink and the refrigerant pressure drop across the heatsink. The overall analysis has shown that micro-channel heat sinks are ideal for dissipating high heat flux as they achieve thermal resistance values of up to 0.0082 K / W. The optimization procedure results in an optimal compromise between the two evaluation criteria which are the thermal resistance and the pressure drop of the coolant, of a contradictory nature. In addition, the gradual introduction of variable-width microchannels is greatly improving.

Chyi-Tsong Chen and Hung I Chen [5] have proposed that the heat sink with air cooling fan is the simplest and most efficient way to disperse the heat generated by a high-tech device. A common approach to optimizing heat sinks is based on minimizing the entropy generation rate which takes into account the two main heat dissipation factors, heat transfer rate and air resistance. However, a lower entropy generation rate often equates to a larger size of the designed heat sink. To have a balanced design of heat sinks for heat dissipation, this article considers minimizing the entropy generation rate and material cost of the heat sinks at the same time.

3. OBJECTIVES

The objective of current research is to conduct thermal analysis of heat sink using FEA and to investigate the effect of individual design parameters on heat dissipation using Taguchi response surface optimization technique. The CAD modelling and FE analysis is conducted using ANSYS software.

4. METHODOLOGY

The CAD model of heat sink is developed in ANSYS design modeler. The sketch is developed as per dimensions and then extruded upto specified depth. The features are then pattern to get multiple copies as shown in figure 1 below.

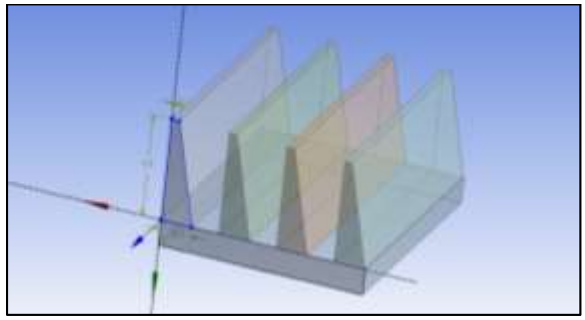

Figure 1: Pattern of single fin

The CAD model of heat sink is meshed using brick elements as shown in figure 2 below. The inflation is set to normal, relevance center is set to fine, smoothing set to medium and transition ratio is set .272.

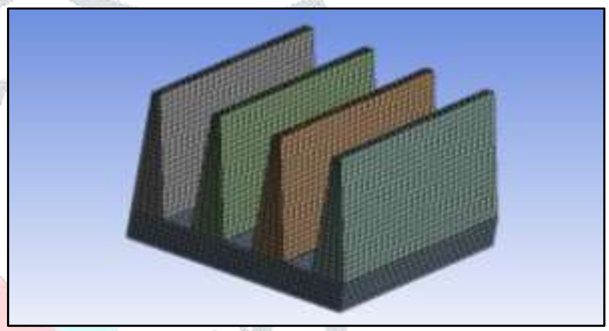

Figure 2: Meshed model of heat sink

The number of nodes generated is 131353 and number of elements generated is 26800. The heat flow of magnitude 20W is applied on bottom face of heat sink made from copper while fins are applied with convection with convective film coefficient of $60W/m^2K$. The ambient temperature is 311K as shown in figure 3 below.

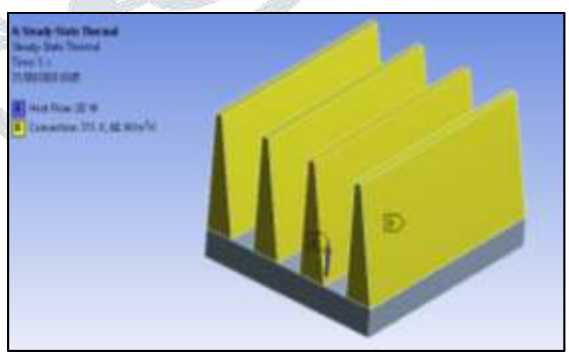

Figure 3: Loads and boundary conditions of heat sink

The solution is then run with sparse matrix solver and with above mentioned loading conditions to ger temperature plot and heat efflux plot.

5. RESULTS AND DISCUSSION

The FE thermal analysis is conducted on base design of heat sink to determine temperature and heat flux.

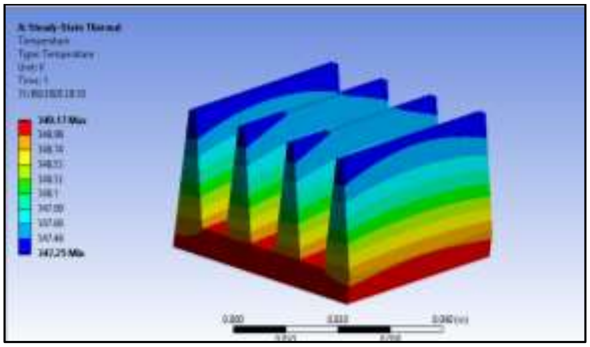

Figure 4: Temperature plot of heat sink

The heat flux of 20W is applied on bottom face of copper plate and temperature generated is maximum at bottom plate shown by dark red colour of magnitude 349.17K and temperature reduces as we move away from base as shown by dark orange and light yellow colour. The temperature at mid of fin is 348K and minimum heat flux is observed at tip of heat sink as shown by dark blue color.

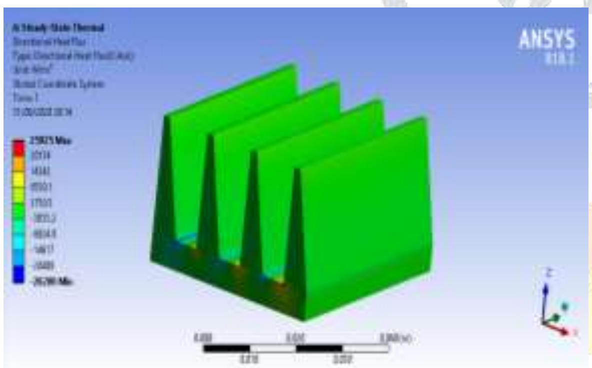

Figure 5: Heat flux along x axis

The heat flux plot for x axis is shown in figure 5 above. The magnitude of maximum heat flux is 25925W/m^2 along positive x direction and 26200 W/m^2 along negative x direction. The heat flux magnitude is uniform for most of the regions of heat sink.

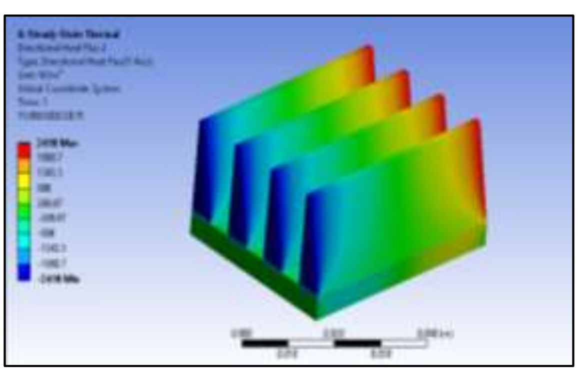

Figure 6: Heat flux along y axis

The heat flux plot for y axis is shown in figure 6 above. The magnitude of maximum heat flux is 2418W/m^2 along positive and negative y direction. This is due to symmetrical geometry of heat sink.

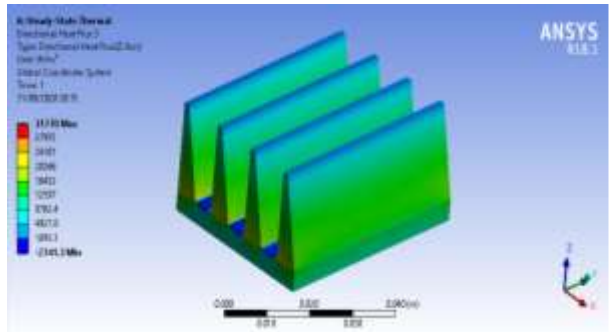

Figure 7: Heat flux along z axis

The heat flux plot for z axis is shown in figure 7 above. The magnitude of maximum heat flux is 31170W/m^2 along positive z direction and 2741.3 W/m^2 along negative z direction. The heat flux on green zone is 16432 W/m^2 on mid zone of aluminium fins.

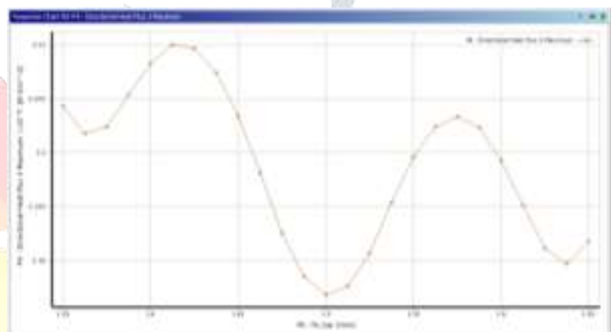

Figure 8: 2D Response surface plot of directional heat flux(z-direction) vs fin_top

As can be observed from figure 8 above, the directional heat flux has two peaks of maximum heat flux under given lower bound and upper bound values. The 1st maximum peak of directional heat flux is observed at 1.42mm fin_top value and 2nd peak value of directional heat flux is observed at 1.57mm fin_top value. The minimum heat flux is observed for fin_top value of 1.5mm.

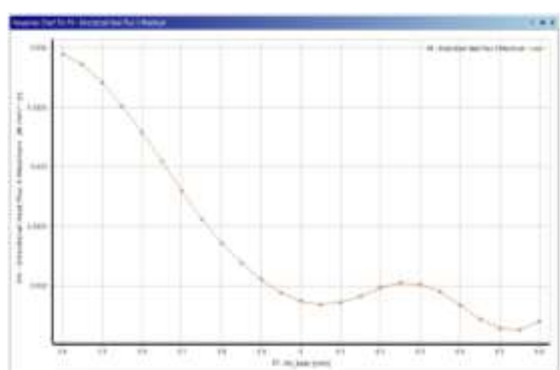

Figure 9: 2D Response surface plot of directional heat flux(z-direction) vs fin_base

As can be observed from figure 9 above, the directional heat flux decreases with increase in fin_base value. The directional heat flux along z-direction decreases linearly upto 6mm and then increases upto 6.3mm and then decreases thereafter.

6. CONCLUSION

The FEA thermal analysis of heat sink used in electronic equipment is conducted using ANSYS software. The temperature plot and heat flux plot provided information on flow of thermal energy. Using response surface optimization technique, the individual effect of each variable i.e. fin_height, fin_top and fin_base is investigated. For directional heat flux along z axis, the fin_height shows negative sensitivity of 8.15, fin_top shows negative sensitivity of 3.13 and fin_base shows negative sensitivity of 32.75. The fin_height, fin_top and fin_base shows negative sensitivity which signifies that with increase in values of these variables, the output parameter (i.e. directional heat flux along z axis) value decreases and vice versa. For directional heat flux along y-axis, the fin_base has highest effect and fin_top has lowest effect. As the heat flux along z direction is most important in dissipation of heat from heat sink, the fin_base is the most significant variable for improving design of heat sink.

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