Lab #11

Thermal Analysis of a Heat Sink

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Department of Mechanical Engineering

ME 37100 Computer Aided Design
Section 1EF
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Abstract

In a thermal analysis of a heat sink, both transient and steady state tests are performed to determine the change to the temperature and heat flux distributions. Convective cooling is explored as it pertains to additions of fins for radiator. Contact resistance temperature between two surface is analyzed for both steady state and transient studies

Introduction

Heat sinks utilize different materials to cool down an intended model. The use of radiators in this lab is seen to determine how temperature is able to escape and where temperature concentration lies. Radiators are an essential part to the function of microchips, therefore observations of heat transfer is important part of designing structures needed for microchips. Varying materials with different thermal properties as well as compensations for heat loss can be increased from changing design. Preliminary studies with FEA can be done to observe temperature distribution, heat flux and thermal resistance, all of which can be used to impact design.

Theoretical Background

In order to determine the cooling effects, the radiator provided for the microchip, the heat flux and temperature distributions must be analyzed. In steady state cases, it assumed that enough time has passed where conditions can be seen to settle to a certain state. Analysis in this portion of the lab will help to determine the resulting plots from a stabilized temperature distribution. In the analysis using a transient study, trends such as how the two materials lose heat can be observed by seeing temperature change at specified locations over time. This can be useful in observing how the two may be changing similarly or different for design.

Thermal contact resistance becomes an important factor due to the presence of a thermal boundary layer. Such analysis helps to determine the resistance that may be needed to overcome or compensated for when designing as well.

Graphical Demonstrations of SolidWorks Results

In the first portion of the lab, a steady state analysis is done on the heat sink with the microchip generating 25 W of heat power to the ambient temerpature of 300 K with a connective coefficient on the exposed surface of 25 W/m^2K. A blende curvature based mesh is applied to the entire structure.

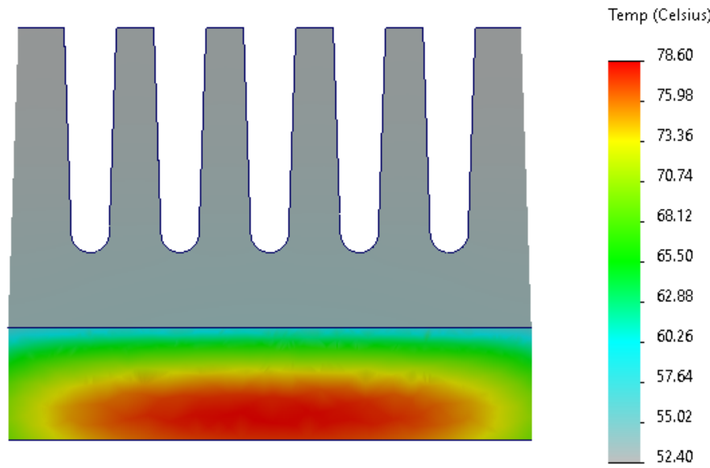

Figure 1: Temperature distribution plot of the steady state heat sink model.

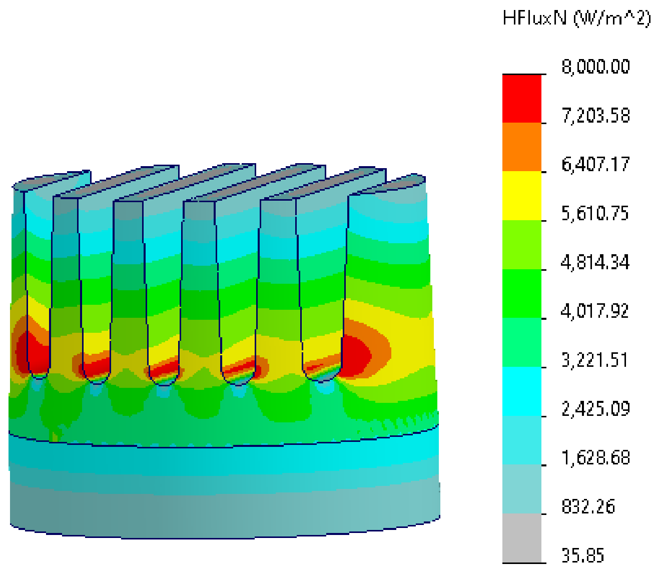

Figure 2: Heat flux plot of the heat sink during steady state.

In the second portion of the lab, transient conditions are considered with the same condition but with a initial temperature specified at 300 K, for a total of 3600 seconds. Results are taken every 360 seconds for a total of 10 steps.

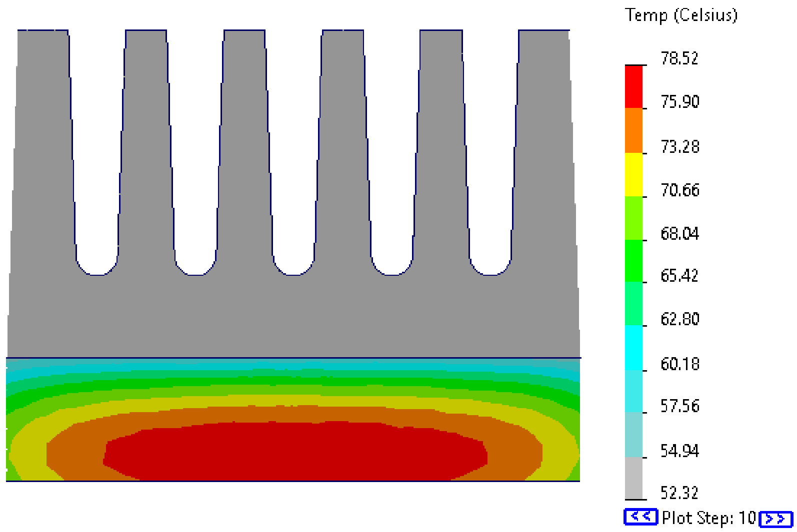

Figure 3: Temperature distribution plot of the transient heat sink model.

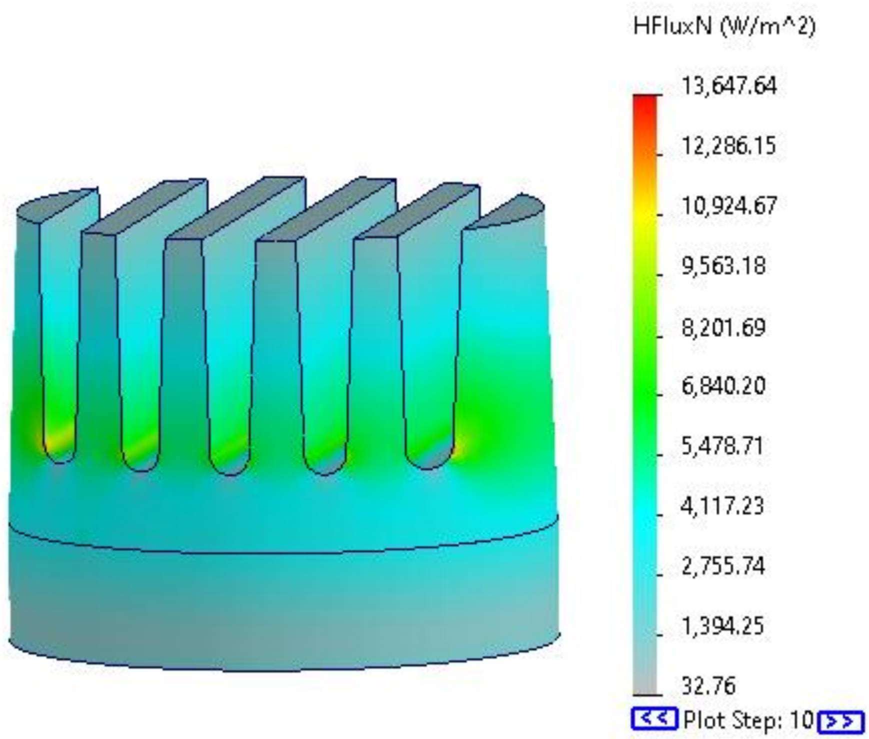

Figure 4: Heat flux plot of the heat sink during transient conditions.

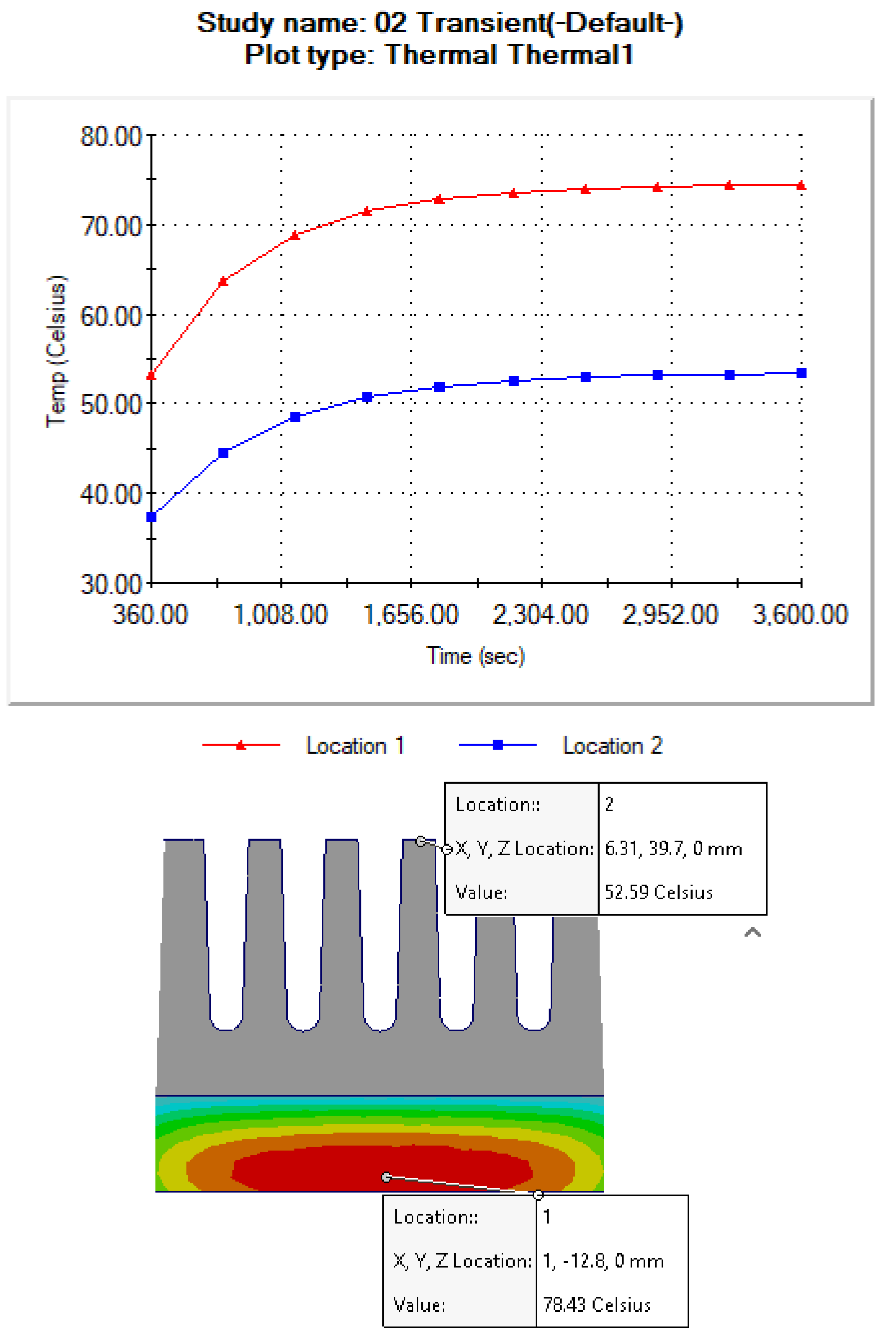

Figure 5: temperature distributions over time of the location 1(red) temperature at center of microchip and location 2(blue) of the heat sink at the outer portion of the fin.

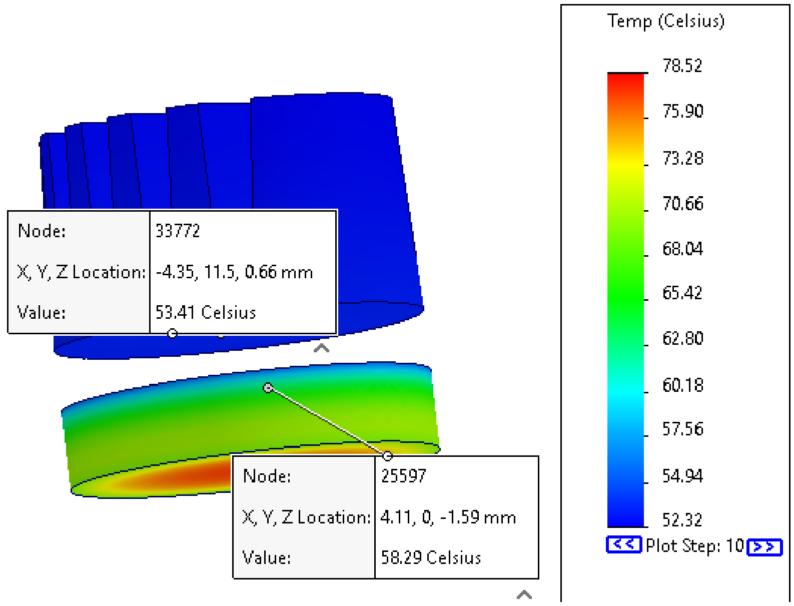

Figure 6: Thermal contact layer of the transient heat sink model.

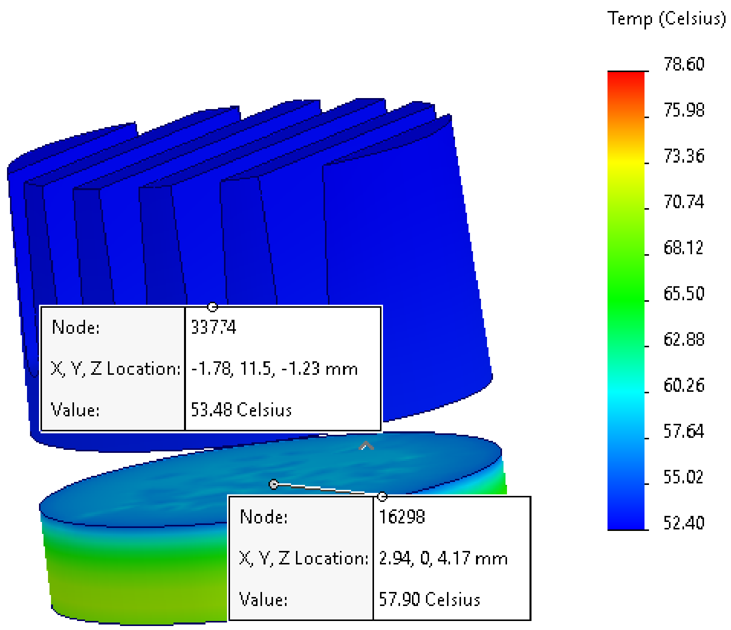

Figure 6: Thermal contact layer of the steady state heat sink model.

Study	Max temperature $(°C)$	Max Heat flux (W/m^2)	Contact layer temperatures $(°C)$	
Steady State	78.60	8000	Radiator	53.48
			Microchip	57.90

Transient	78.52	13,647.64	Radiator	53.41
			Microchip	58.29

Figure 7: Tabulated results of both steady state and transient study of the heat sink.

Discussion and Interpretation of Results

Both the steady state and transient study of the heat sink is meant to observe the temperature distributions given a specified heat power from the microchip. The radiator is seen in both cases to have the low, uniform temperature distributions (figures 1 & 3). Heat is seen to be highest in the central portion of the microchip, where it is furthest from the atmosphere. Such results is expected as the shape of the radiator provided more exposed surfaces to the ambient temperature. It can also be seen that the heat is seen to escape in the portions lower in the radiator (figures 2 & 4). Both the transient and steady state temperature distribution is seen to be similar, indicating that the heat loss is not converging to a point where heat is seen to leave at a certain rate. As seen in the graph (figure 5), at the point of lowest temperature and highest temperature, where the heat loss was seen to be curved and increasing for the first 1,000 seconds, the slope quickly decreased indicating that the microchip is limited to decreasing to a temperature of around 78-79 $°C$.

In observing the thermal resistance of the radiator to the microchips due to the thermal boundary layer, it can be seen that the radiator have around a 4-5 $°C$ difference from the microchip. Such a results indicates the thermal boundary layer presence and must therefore be accounted for in design. The difference in temperature is obvious as well in the temperature distribution plots in which there are no gradient temperature change between the 2 materials.

Conclusions

Observations were made in determining the effects of time in the temperature distributions of a heat sink from a generated heat power of the microchip. It was seen that the temperature change converged to around 78-79 $°C$ at the maximum temperature point. Heat flux plots were made to determine where the heat sink was losing heat and helping to determine the effects of the geometry on the heat loss. Thermal resistance between the radiator and microchips was seen to be present and must be considered as a parameter in designing for heat reductions.

References

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[2] A First Course in the Finite Element Method, Enhanced Edition, 6th Ed., by Daryl Logan (2022), ISBN-10: 0357884140.
[3] Finite element simulation: A user's perspective, Chris V. Nielson (2021), https://doi.org/10.1016/B978-0-323-85255-5.00011-X.