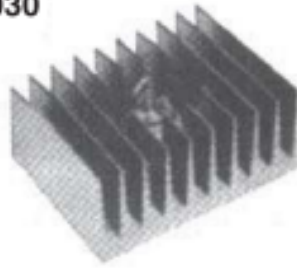


HS 5030



HEAT SINK FIN DESIGN & ANSYS THERMAL SIMULATION

Theoretical Analysis vs. Numerical Simulation of Extended Surfaces

Applied Heat Transfer (ETM 3081)

Heat Sink Model Selected: HS 5030

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Section 1: Analytical Calculations

Heat Sink Selection:

Heat Sink	Dimensions (mm)	R (°C/W)	Surface Area (cm ²)
HS 5030	76 × 105 × 44	0.9 (vert) / 1.2 (horiz)	677

Heat sink made of Aluminum 6063-T5, is black anodized, and 76 mm (3 in) long.

Given Data & Material Properties:

Property	Value
Fin material	Aluminum 6063-T5
Thermal conductivity (k)	200 W/m·K
Density (ρ)	2700 kg/m ³
Specific heat (c_p)	900 J/kg·K
Emissivity (black anodized)	0.86

Operating Conditions:

Parameter	Value
Base temperature (T_b)	80°C (set by electronics)
Ambient temperature (T_∞)	25°C
Convection coefficient (h)	12 W/m ² ·K (natural convection)
Power dissipation	60 W (transistor heat load)

Analytical Fin Parameter Calculations:

Calculated Quantity	Your Value
Fin length L (m)	0.04 m
Fin thickness t (m)	0.002 m
Fin width w (m)	0.076 m
Perimeter p (m)	0.156 m
Cross-sectional area A_c (m ²)	0.000152 m ²
Fin parameter m (m ⁻¹)	7.85 m ⁻¹

Corrected length L_c (m)	0.041 m
mL_c (dimensionless)	0.322
Fin efficiency η_{fin} (%)	96.6%
Fin surface area A_{fin} (m ²)	0.006232 m ²
$Q_{fin, max}$ (W)	4.11 W
Q_{fin} (actual) (W)	3.97 W
Fin effectiveness ε_{fin}	39.6

Overall Heat Sink Performance:

Calculated Quantity	Value
Number of fins	10
Total finned area (m2)	0.06232
Base area (m2)	0.00798
Unfinned base area (m2)	0.00646
Total heat transfer (W)	44.03197959
Overall fin effectiveness	8.360290801
Thermal resistance (°C/W)	1.249092149
Manufacturer Vertical resistance (°C/W)	0.9
Manufacturer Horizontal resistance (°C/W)	1.2

Discussion:

The analytical thermal resistance was 1.249 C/W, which is very close to the manufacturer's horizontal value of 1.2 C/W and higher than the vertical value of 0.9 C/W. This difference is reasonable because the catalog values depend on orientation and manufacturer test conditions, while the analytical model uses simplified geometry and a uniform convection coefficient.

Work for Fin Parameter (Calculated in spreadsheet):

Perimeter:

$$p = 2(w + t)$$

$$p = 2(0.076 + 0.002) = 0.156 \text{ m}$$

Cross-sectional area:

$$A_c = w \times t$$

$$A_c = 0.076 \times 0.002 = 0.000152 \text{ m}^2$$

Fin parameter:

$$m = \sqrt{hp / kA_c}$$

$$m = \sqrt{(12 \times 0.156) / (200 \times 0.000152)} = 7.847 \text{ m}^{-1}$$

Corrected length:

$$L_c = L + t/2$$

$$L_c = 0.040 + 0.001 = 0.041 \text{ m}$$

mLc:

$$mL_c = 7.847 \times 0.041 = 0.3217$$

Fin efficiency:

$$\eta_{\text{fin}} = \tanh(mL_c) / (mL_c)$$

$$\eta_{\text{fin}} = \tanh(0.3217) / 0.3217 = 0.9669 = 96.69\%$$

Fin surface area:

$$A_{\text{fin}} = 2wL_c$$

$$A_{\text{fin}} = 2 \times 0.076 \times 0.041 = 0.006232 \text{ m}^2$$

Maximum possible heat transfer:

$$Q_{\text{fin,max}} = hA_{\text{fin}}(T_b - T_{\infty})$$

$$Q_{\text{fin,max}} = 12 \times 0.006232 \times (80 - 25) = 4.113 \text{ W}$$

Actual heat transfer from one fin:

$$Q_{\text{fin}} = \eta_{\text{fin}} \times Q_{\text{fin,max}}$$

$$Q_{\text{fin}} = 0.9669 \times 4.113 = 3.977 \text{ W}$$

Fin effectiveness:

$$\epsilon_{\text{fin}} = Q_{\text{fin}} / [hA_b(T_b - T_{\infty})] \text{ then } A_b = w t = 0.000152 \text{ m}^2$$

$$\epsilon_{\text{fin}} = 3.977 / [12 \times 0.000152 \times 55] = 39.64$$

Work for Heat Sink Performance (Calculated in spreadsheet):

Total finned area:

$$A_{\text{fin,total}} = n_{\text{fin}} \times A_{\text{fin}}$$

$$A_{\text{fin,total}} = 10 \times 0.006232 = 0.06232 \text{ m}^2$$

Base area: $A_{\text{base}} = 0.105 \times 0.076 = 0.00798 \text{ m}^2$

Unfinned base area:

$$A_{\text{unfin}} = A_{\text{base}} - n_{\text{fin}}(t \times w) \text{ then } A_{\text{unfin}} = 0.00798 - 10(0.002 \times 0.076) = 0.00646 \text{ m}^2$$

Total heat transfer:

$$Q_{\text{total}} = hA_{\text{unfin}}(T_b - T_{\infty}) + \eta_{\text{fin}} h A_{\text{fin,total}} (T_b - T_{\infty})$$

$$Q_{\text{total}} = 12 \times 0.00646 \times 55 + 0.9669 \times 12 \times 0.06232 \times 55 = 44.04 \text{ W}$$

Overall effectiveness:

$$\epsilon_{\text{overall}} = Q_{\text{total}} / [hA_{\text{no-fin}}(T_b - T_{\infty})] \text{ then } A_{\text{no-fin}} = A_{\text{base}} = 0.00798 \text{ m}^2$$

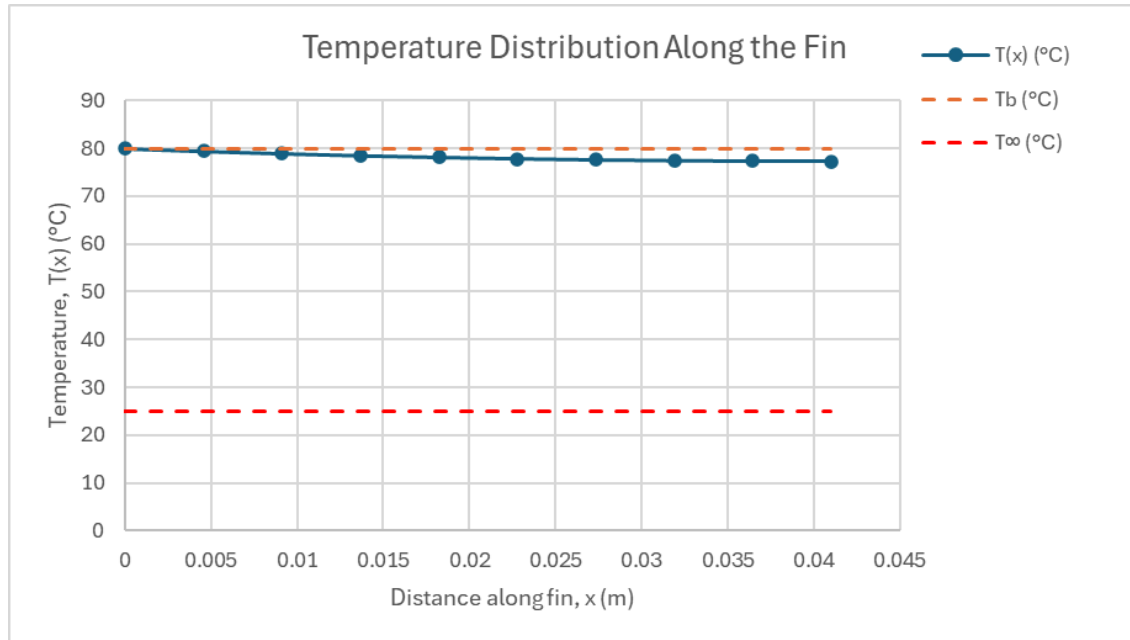
$$\epsilon_{\text{overall}} = 44.04 / [12 \times 0.00798 \times 55] = 8.36$$

Thermal resistance:

$$R = (T_b - T_{\infty}) / Q_{\text{total}}$$

$$R = 55 / 44.04 = 1.249 \text{ C/W}$$

Section 2: Analytical Temperature Distribution Plot



Analytical temperature distribution along the representative fin, showing $T(x)$ from the base to the corrected fin tip.

Verification:

$$T(0) = 80 \text{ C} = T_b$$

$$T(L_c) = T(0.041) = 77.27 \text{ C}$$

Since 77.27 C is greater than 25 C, the fin tip approaches the ambient temperature but does not reach it.

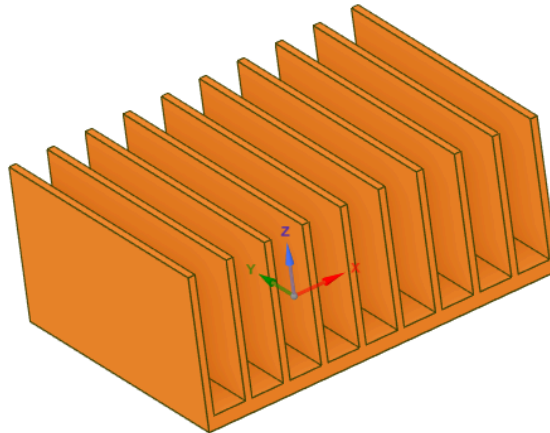
Discussion:

The analytical temperature profile decreases gradually from 80 C at the base to 77.27 C at the corrected fin tip. Since $mL_c = 0.3217$ and a value near 1 is considered a good compromise, the fin is relatively short and remains highly efficient.

Section 3: ANSYS Simulation

Geometry

A simplified HS 5030 heat sink model was created in ANSYS using the estimated dimensions from the analytical model:

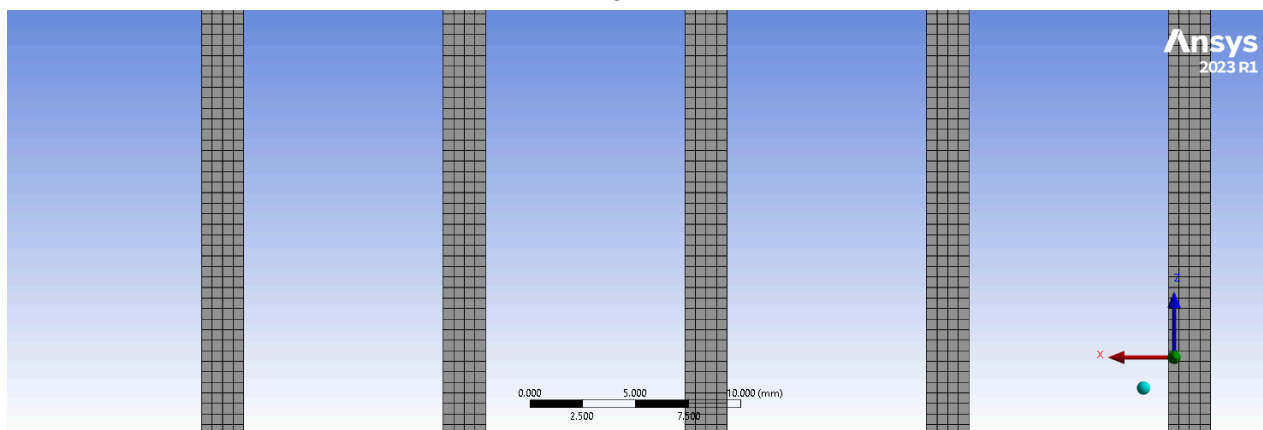


Area	79808mm ²
X Overall	105mm
Y Overall	76mm
Z Overall	44mm

Simplified 3D ANSYS geometry of the selected HS 5030 heat sink with overall dimensions annotated.

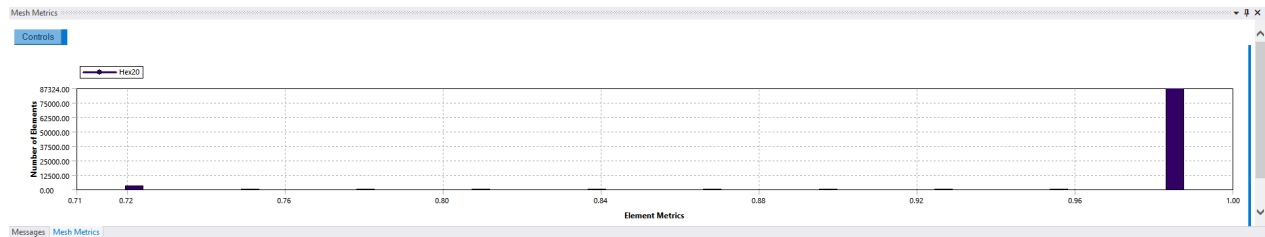
Meshing

The model was meshed in ANSYS Mechanical. A body sizing of 0.50 mm was used, and a close-up confirmed at least two elements through the 2 mm fin thickness:



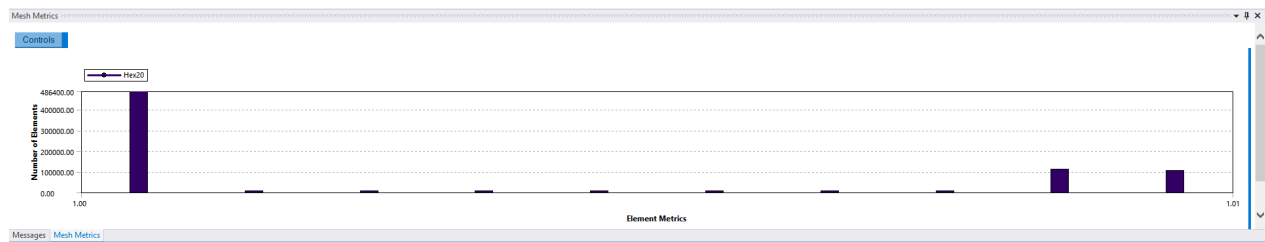
Close-up of the ANSYS mesh showing more than two elements through the 2 mm fin thickness.

Element Quality:



Mesh quality distribution for the ANSYS model, confirming acceptable element quality.

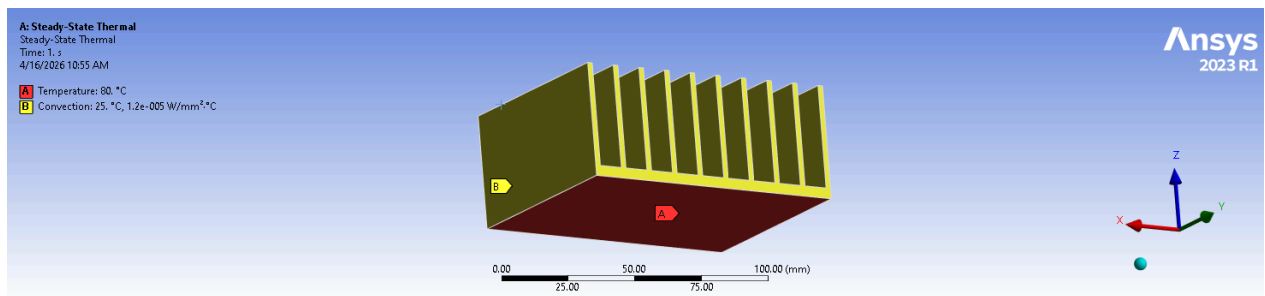
Aspect ratio:



Mesh aspect ratio distribution for the ANSYS model, confirming an acceptable element aspect ratio.

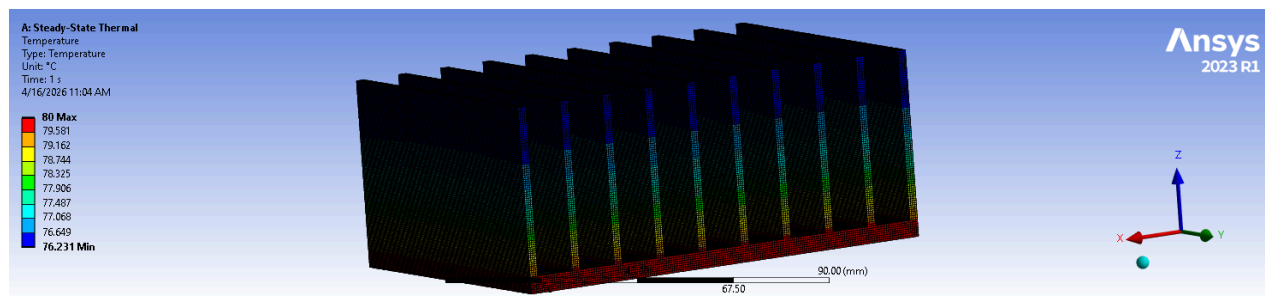
Boundary Conditions

The bottom face of the base plate was assigned a fixed temperature of 80 C. Convection was applied to all exposed outer surfaces with $h = 12 \text{ W/m}^2\cdot\text{K}$ and ambient temperature 25 C.

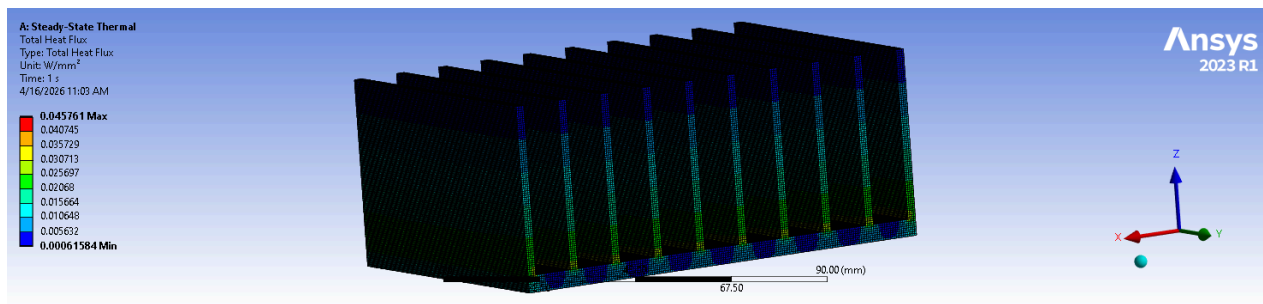


ANSYS boundary condition setup showing a fixed 80 C temperature at the base and convection on all exposed outer surfaces.

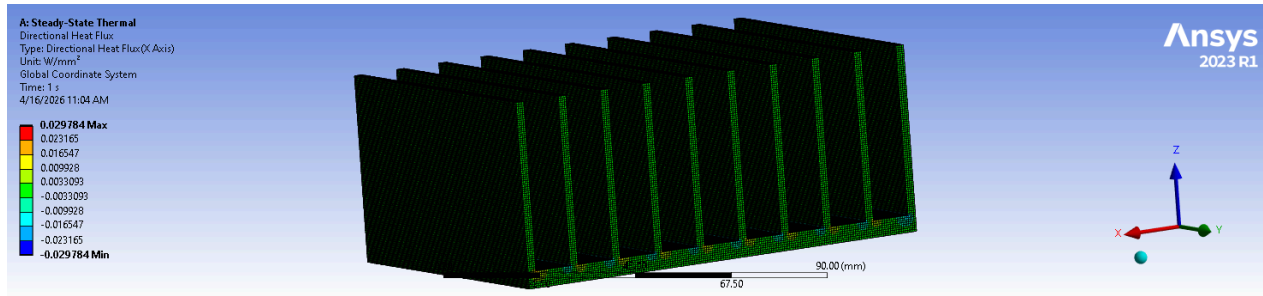
Solution Results:



ANSYS temperature contour of the HS 5030 heat sink under steady state thermal loading.



ANSYS total heat flux contour showing heat transfer distribution throughout the heat sink.

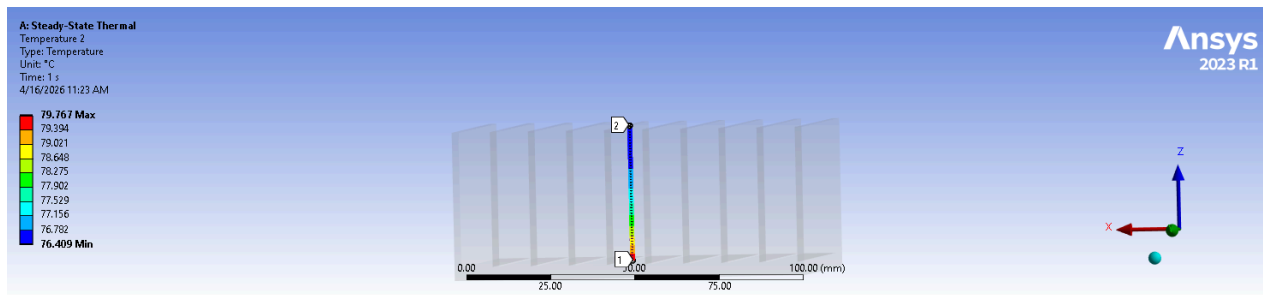


ANSYS directional heat flux contour in the fin length direction.

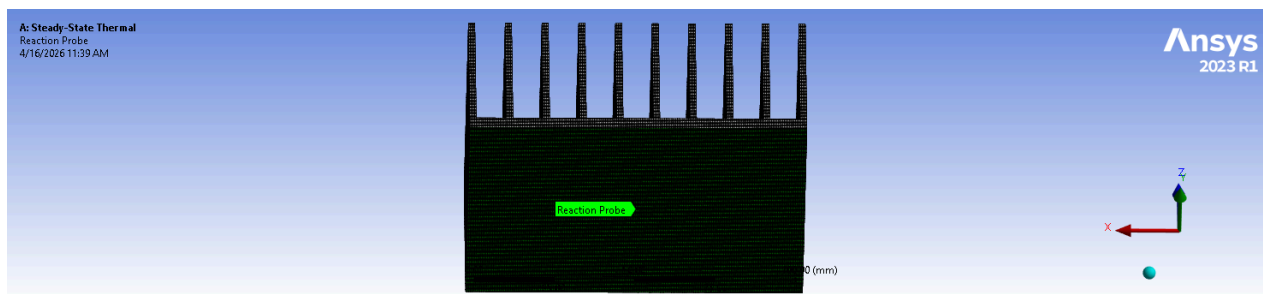
Section 4: Post Processing

Temperature Path Plot

A path was created along the center of a representative fin from base to tip. The ANSYS path data showed the temperature decreasing from 79.767 C at the base to 76.409 C at the fin tip.



ANSYS temperature path plot along the center of a representative fin from base to tip.



ANSYS reaction probe result at the fixed temperature base face, used to determine total heat dissipation.

Summary Table of ANSYS Results:

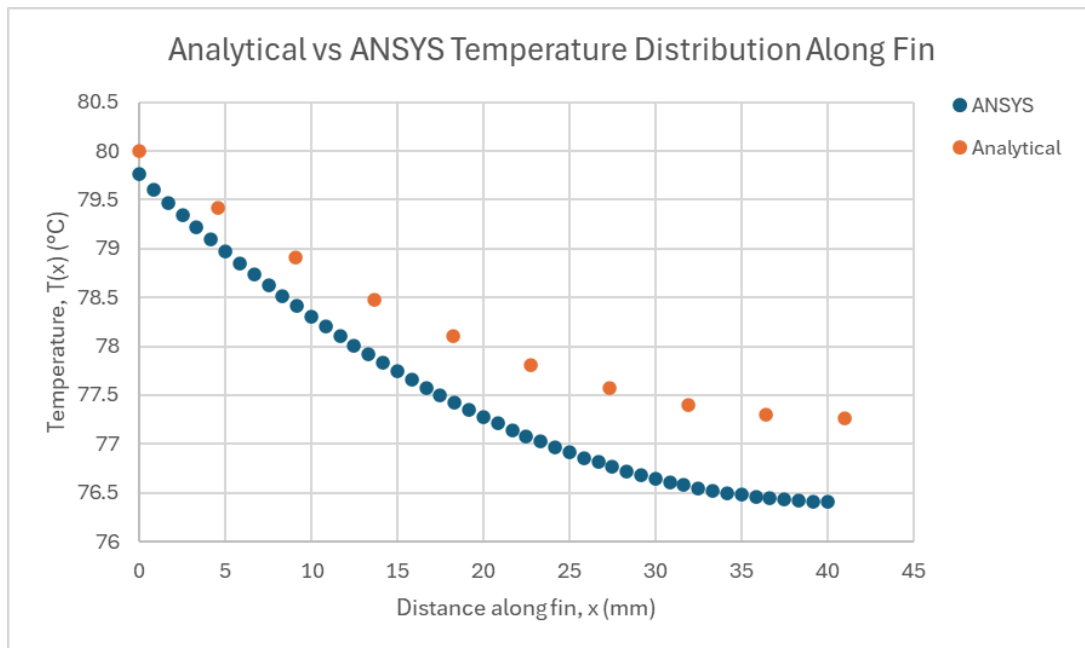
Calculated Quantity	ANSYS Value
Base temperature at $x = 0$ mm, °C	79.767
T at $x = 10$ mm, $L/4$, °C	78.306
T at $x = 20$ mm, $L/2$, °C	77.277
T at $x = 30$ mm, $3L/4$, °C	76.645
Fin tip temperature at $x = 40$ mm, °C	76.409
Minimum temperature from contour, °C	76.231
Maximum temperature from contour, °C	80.000
Average temperature from contour, °C	78.288
Heat flux at base face, W	45.459
Total heat dissipation through base, W	45.459

Section 5: Comparison**Comparison Table:**

Quantity	Analytical	ANSYS	% Difference
Base temperature (°C)	80.000	79.767	0.29
Tip temperature (°C)	77.269	76.409	1.11
Heat transfer per fin (W)	3.977	N/A, full sink modeled	N/A
Fin efficiency (η_{fin})	0.9669	N/A, full sink modeled	N/A
Thermal resistance (°C/W)	1.249	1.210	3.12
T at $x = L/4$ (°C)	78.830	78.306	0.66
T at $x = L/2$ (°C)	77.980	77.277	0.90
T at $x = 3L/4$ (°C)	77.460	76.645	1.05

Because the ANSYS model included the full heat sink rather than a single isolated fin, the ANSYS heat transfer per fin and fin efficiency were not directly extracted from the simulation.

Overlay Plot:



Overlay of the analytical temperature distribution and the ANSYS fin centerline temperature path.

Thermal Resistance from ANSYS:

$$R_{\text{ANSYS}} = (T_b - T_{\infty}) / Q_{\text{total,ANSYS}}$$

$$R_{\text{ANSYS}} = (80 - 25) / 45.459 = 1.210 \text{ C/W}$$

Biot Number Check:

$$h(t/2)/k = 12(0.001)/200 = 0.00006$$

Since 0.00006 is less than 0.2, the one-dimensional fin assumption is valid.

Mesh Refinement Study:

The original mesh used a 0.50 mm body sizing, and a refined mesh with 0.45 mm body sizing was also solved. The change in the key result was less than 1 percent, so the original mesh was considered sufficiently refined and mesh independent for this project. The ANSYS path data were exported to CSV and used in Excel for the comparison and overlay plot.

Discussion:

The ANSYS results agreed closely with the analytical model. The base, tip, and intermediate temperatures differed by about 1 percent or less, while total heat dissipation and thermal resistance differed by about 3 percent. These differences are reasonable because the analytical model assumes one-dimensional conduction, simplified geometry, and an adiabatic tip correction, while ANSYS models three-dimensional conduction and convection over the full fin array.

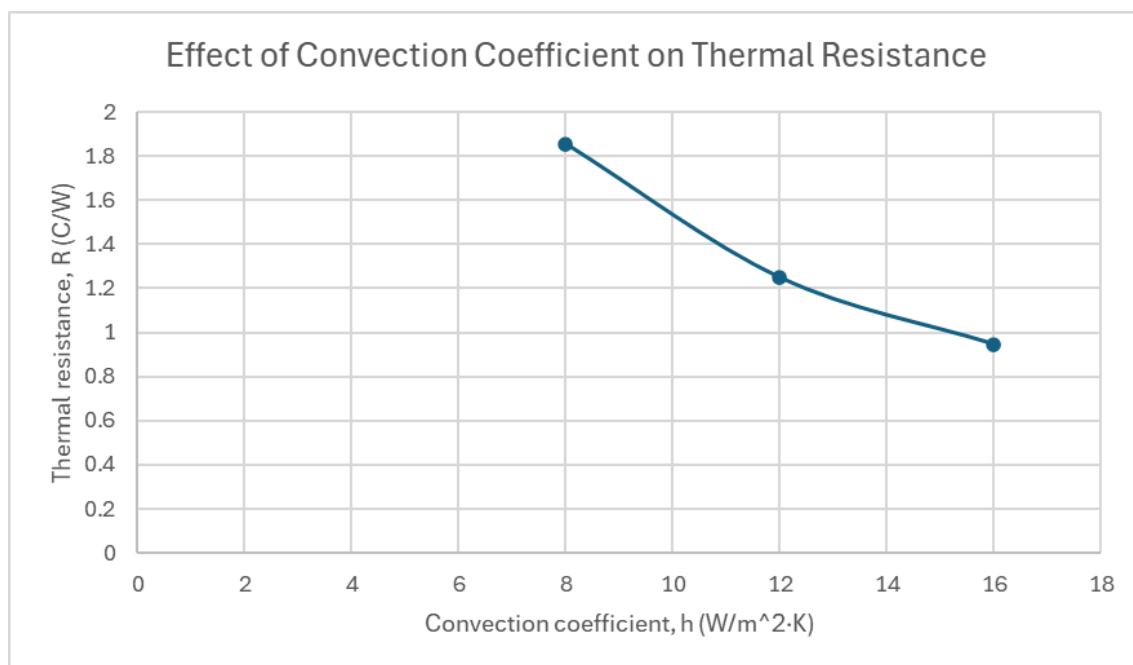
Section 6: Parametric Study Results and Plots

A simple analytical parametric study was performed by varying the convection coefficient, h , while keeping the fin geometry and temperatures constant. Three cases were evaluated: $h = 8$, 12, and 16 $\text{W/m}^2\cdot\text{K}$. As h increased, the total heat transfer increased, and the thermal resistance decreased. This trend is expected because stronger convection improves heat removal from the heat sink surface.

Parametric Table:

h ($\text{W/m}^2\cdot\text{K}$)	m (m^{-1})	η_{fin}	Q_{fin} (W)	Q_{total} (W)	R (C/W)
8	6.407	0.9776	2.681	29.469	1.855
12	7.847	0.9669	3.977	44.032	1.249
16	9.061	0.9564	5.245	58.136	0.946

Parametric Plot:



Effect of convection coefficient on thermal resistance for the analytical heat sink model.

Section 7: Conclusions and Lessons Learned

This project was used to evaluate the thermal performance of the HS 5030 heat sink using both analytical fin calculations and a steady-state thermal simulation in ANSYS. Overall, the two methods matched pretty well and gave results that were close enough to show the analytical model was a good approximation for this heat sink. The analytical model predicted a total heat transfer of 44.04 W and a thermal resistance of 1.249 C/W, while the ANSYS model predicted 45.459 W and 1.210 C/W. The temperatures along the fin also stayed fairly close, with only small differences between the analytical and simulated values.

These results support the use of the one-dimensional fin assumption for this geometry. The Biot number check was much smaller than the required limit, which means the assumption was valid. The mesh refinement study also showed very little change when the mesh was made slightly finer, so the ANSYS results were considered stable. Even though the results were close, some difference was still expected because the analytical model uses simplified assumptions like one-dimensional conduction, uniform convection, and corrected fin length, while ANSYS models the full three-dimensional heat sink and its full surface exposure.

Overall, this project showed that standard heat transfer equations can give a solid estimate of real heat sink performance when the assumptions are reasonable. It also showed that ANSYS is useful for confirming the analytical results and for showing how temperature and heat flow are distributed through the full heat sink. This project helped connect the hand calculations to a more realistic engineering simulation and gave a better understanding of how fin geometry, convection, and modeling assumptions affect thermal performance.