Heat Transfer

Computational Assignment - Conduction

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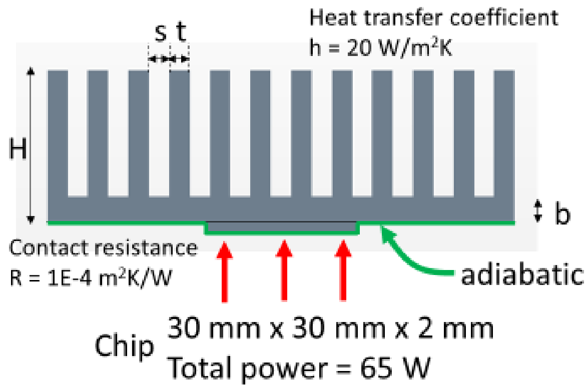
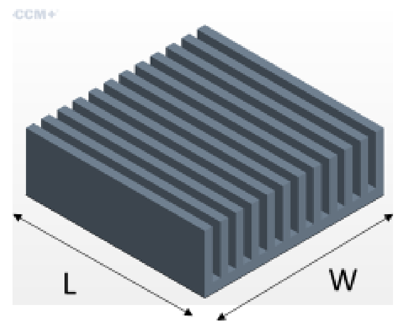
Consider a chip attached to a heat sink as shown in the figure below. The chip thickness is 2 mm and other dimensions are provided in the figure. The chip is made of silicon and the heat sink is made of iron.

L (mm)	W (mm)	H (mm)	t (mm)	s (mm)	b (mm)	Number of fins	Material
92	92	30	4	4	5	12	HS: Fe Chip: Si





1. During the lab session, you used STAR-CCM+ to compute the steady state temperature distribution in the chip-heat sink assembly.
   a) What was the maximum temperature in the chip?

   Result:
   The maximum temperature in the chip is **372.23˚C**.

   b) How many iterations did you run the program? Did you ensure that a certain convergence criterion was reached? (screen shot of the residual plot would be fine)

   Result:
   (i) I run the program for **1370 iterations**.
   (ii) A certain convergence criterion was reached as **the residual approaches zero**.

Iteration	Energy	最大值 1 (K)
1361	1.032619e-03	3.722254e+02
1362	1.028676e-03	3.722265e+02
1363	1.024749e-03	3.722275e+02
1364	1.020836e-03	3.722286e+02
1365	1.016939e-03	3.722296e+02
1366	1.013056e-03	3.722307e+02
1367	1.009188e-03	3.722317e+02
1368	1.005335e-03	3.722327e+02
1369	1.001497e-03	3.722338e+02
1370	9.976730e-04	3.722348e+02

Figure 1.1: The iteration and maximum temperature

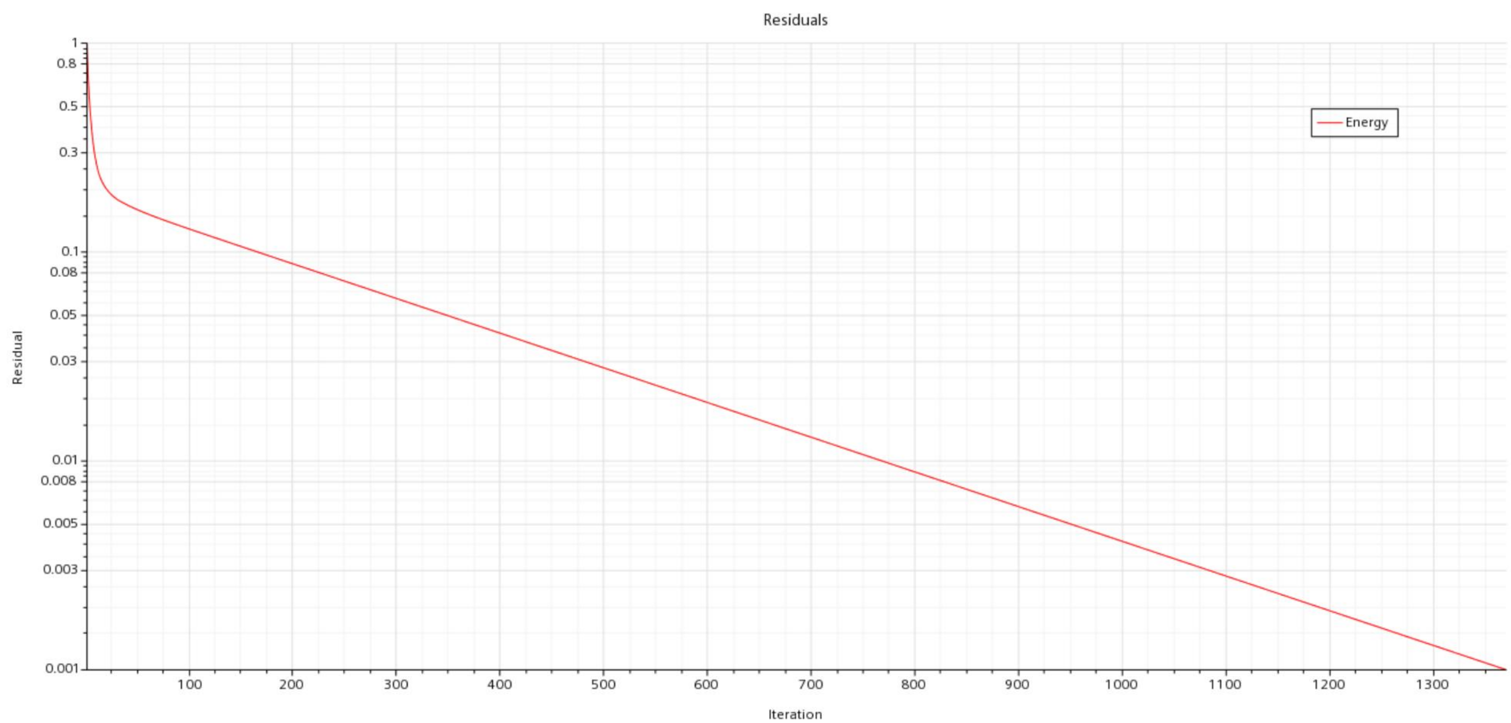


Figure 1.2: The residual plot

2. You want to reduce the maximum temperature obtained in your computational simulation by at least 7°C. Change some features of the heat sink (e.g. thickness of fins, number of fins, heat sink material) that is likely to make the heat sink more effective and reduce the maximum temperature. Modify the computational model appropriately and re-run to obtain a new maximum temperature. Report the new temperature as well as provide computational temperature variation (image from a screen shot would be fine) in the original and the new model. Please demonstrate at least one design variation and add reasoning behind the design change.

Design variation :

I change **the material of the fins** from **Fe** to **Cu**.

Result:

(i) The new maximum temperature: **359.01** after 6557 iterations.

(ii) The original maximum temperature: **372.23** after 1370 iterations.

(iii) The difference of the maximum temperature: 372.23°C -359.01°C =**13.22°C >7°C**

Iteration	Energy	最大值 1 (K)
6551	1.004570e-03	3.590082e+02
6552	1.003770e-03	3.590084e+02
6553	1.002970e-03	3.590086e+02
6554	1.002171e-03	3.590088e+02
6555	1.001372e-03	3.590090e+02
6556	1.000574e-03	3.590092e+02
6557	9.997768e-04	3.590094e+02

Figure 2.1: The iteration and maximum temperature of modified computational model

Computational temperature variation:

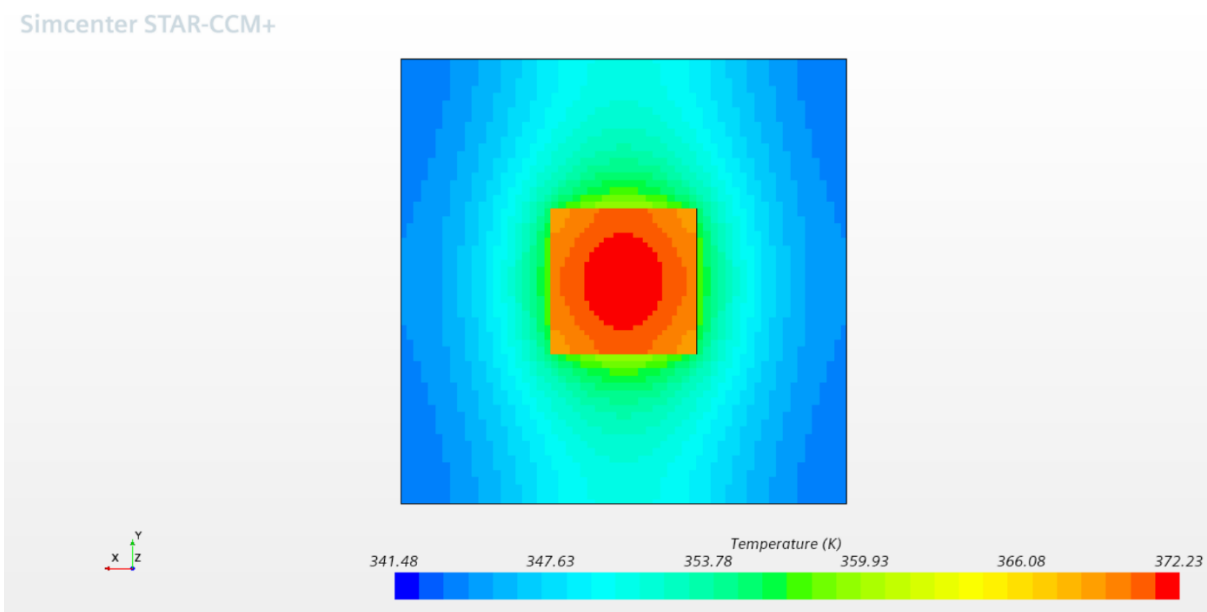


Figure 2.2.1: The temperature variation of the original model

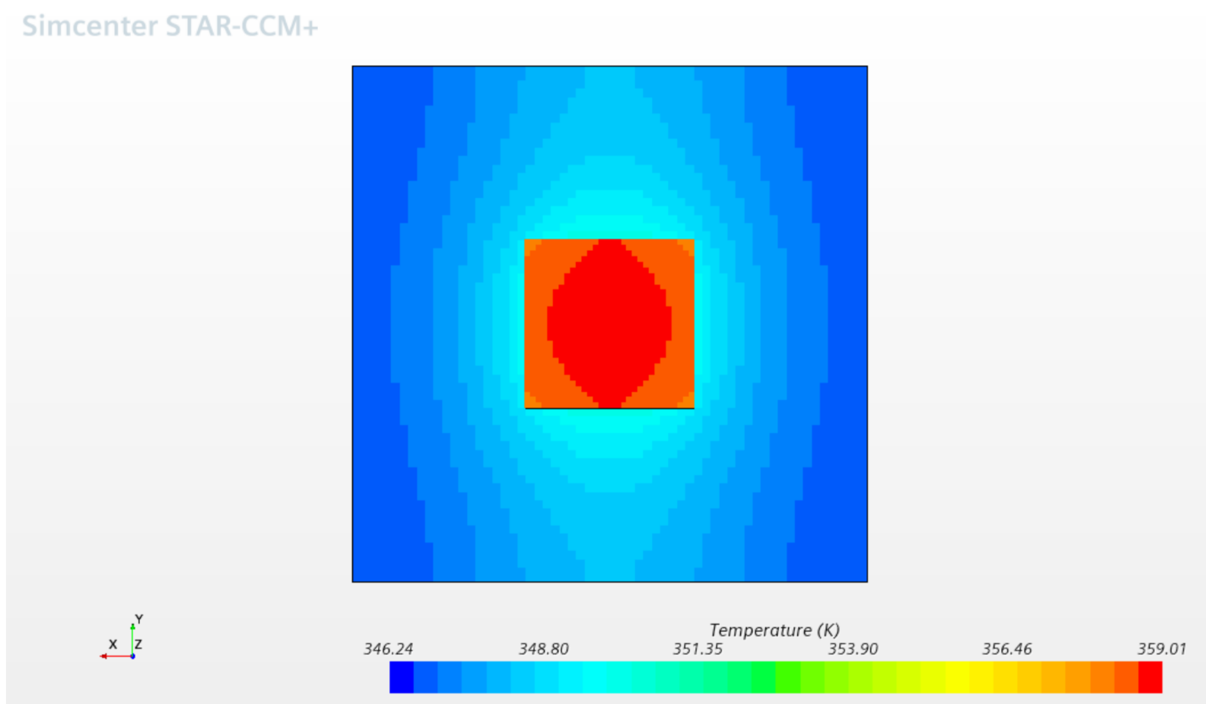


Figure 2.2.2: The temperature variation of the modified model

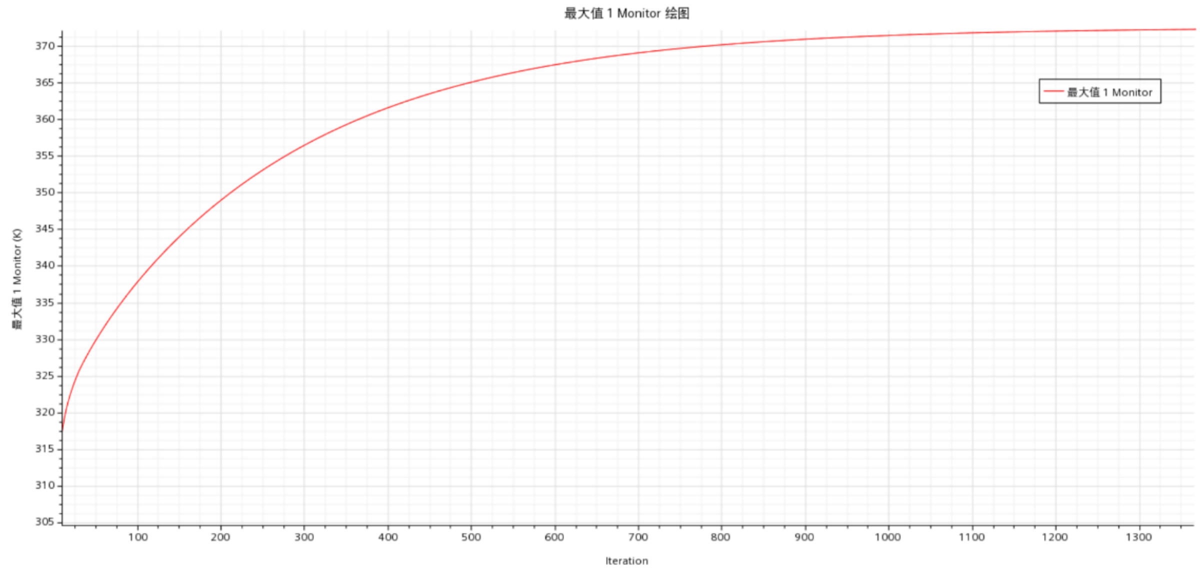


Figure 2.3.1: The maximum temperature changing with iteration of the original model

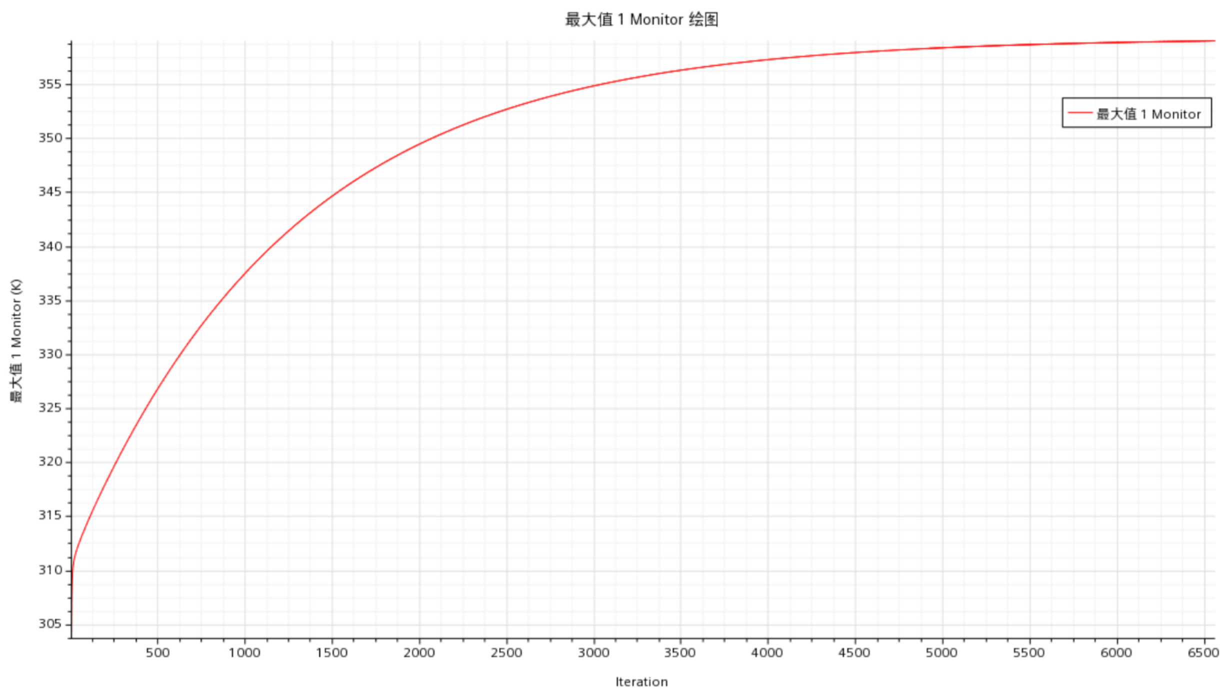


Figure 2.3.2: The maximum temperature changing with iteration of the modified model

Reason behind the design change:

The coefficient of heat transfer of the copper (Cu) is about k_{Cu}=377W/(m·K), while The coefficient of heat transfer of the iron (Fe) is about k_{Fe} = 80W/(m·K).

According to the lecture, we have learnt that, the fin heat transfer rate in **Case II** can be calculated as

$$q_{fin} = \sqrt{\bar{h}_c PAk\theta s}\tanh mL$$

where q_{fin} is the fin heat transfer rate, $\bar{h}c$ is the heat transfer coefficient between the surface of the fin and the fluid, P is the perimeter of the pin, A is the area of the heat transfer, k is the thermal conductivity of the fins, θ_s=T_s-T_∞, m^2=$\bar{h}c\ P/kA$, L is the length of the fins.

Although the computational model we built is **not compeletely the same as Case II**, we can still see that, **the higher the thermal conductivity** is , **the larger the fin heat transfer rate** is.

As $\boldsymbol{k_{Cu}> k_{Fe}}$, , **the maximum temperature would decrease** if we **use the copper** as the material of the fins **instead of the iron**.

What's more, we can also find that if we **reduce the thickness of fins**, in order to **add the number of fins**, then **the area of the heat transfer will increase**, and the **the maximum temperature obtained would alse decrease**.