2D Conduction Lab

Brandon Lim
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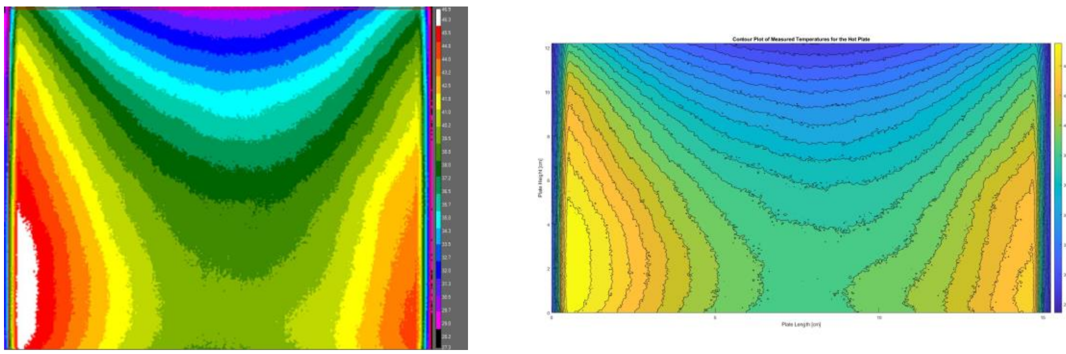

Figure 1a. Experimental thermal image displayed by the infrared camera of the 2D conduction in the alumium plate (left). Countour plot of the measured temperatures from the infrared camera of the 2D conduction in the alumium plate using 20 isotherms (right). The x and y axis are the plate length and height in centimeters respectively. A color bar accompanies each image where the color is associated with a temperature in degrees Celsius.

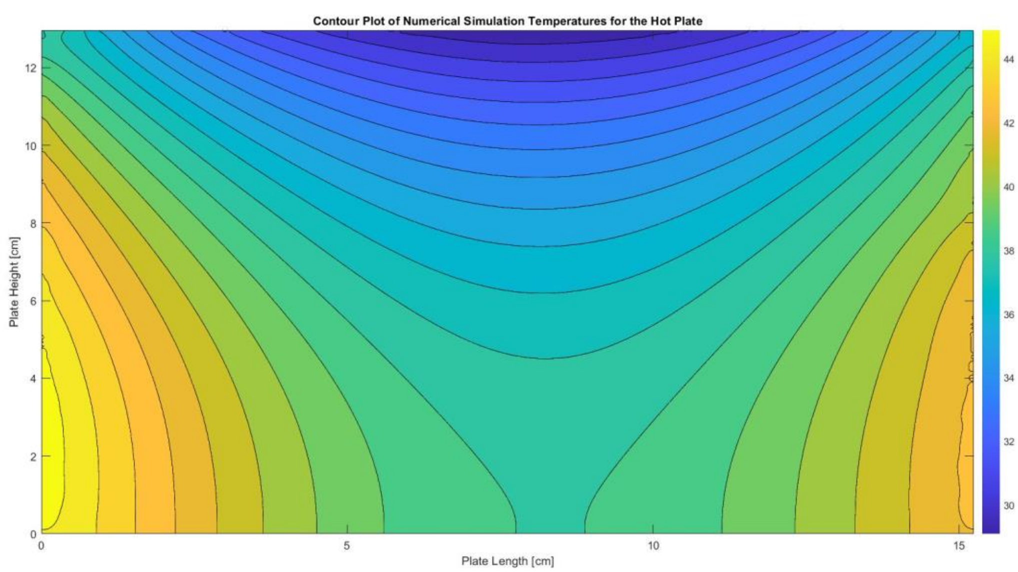

Figure 1b. Numerical simulation results of computed temperatures for the hot plate with 20 isotherms. Values were computed using temperature boundary conditions at the left, right, and top edges. Interior and bottom edge temperatures were found using gauss seidel numerical simulation. The x and y axis are the plate length and height in centimeters respectively. A color bar accompanies the image where the color is associated with a temperature in degrees Celsius.

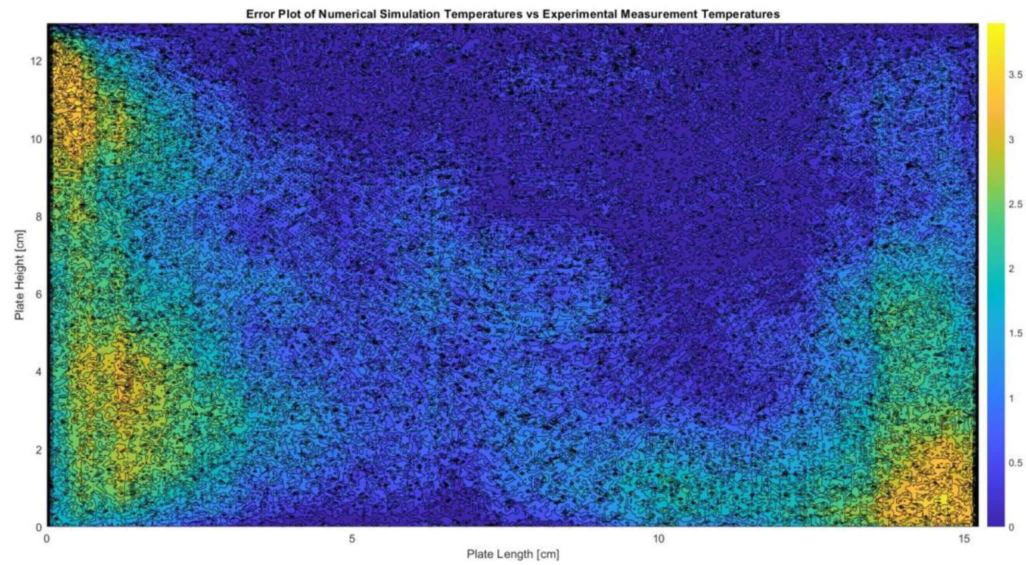

Figure 1c. Error plot of numerical simulation temperatures vs experimental measured temperatuers. The x and y axis are the plate length and height in centimeters respectively. A color bar accompanies the image where the color is associated with a temperature difference between the numerical and experimental results in percentage.

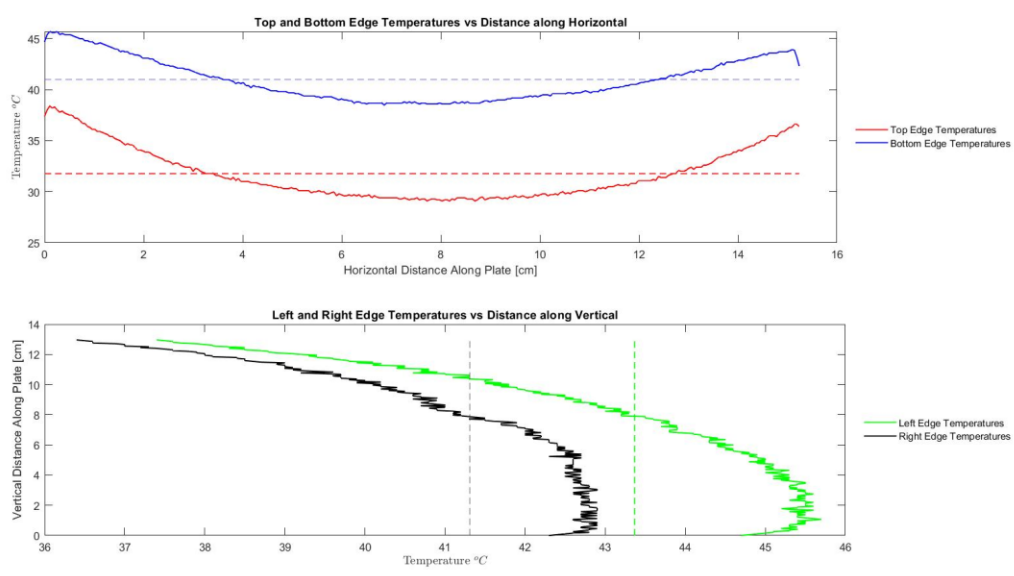

Figure 1d. Plot of measured top and bottom edge temperatures in degrees Celsius on the y-axis vs horizontal distance along the plate in centimeters on the x-axis(top plot). Plot of measured right and left edge temprreratures in degrees Celsius on the x-axis vs vertical distance along the plate in centimers on the y-axis (bottom plot). The dashed lines represent the mean temperature for each edge in their respective colors.

Table 1e. Net heat transfer in Watts across each boundary edge. The middle column represents calculated heat transfer rates using forward and backwards finite difference methods while the far right column represents calculated heat transfer from voltage and current measurements.

Edge	q (W)	P_E (W)
Left	-124.32	-322.94
Top	13.73	54
Right	86.86	55.8
Bottom	-3.09	0

Short-Answer Questions

2a. Quantify (in terms of a percentage) the average difference between the measured and computed temperatures, i.e., average $\epsilon_{i,j}$ spatially over the entire domain. Are there regions in the domain where the differences are greater than the average? Explicitly state the maximum percent difference, and indicate where that occurs in the domain. Are there any trends observed in the difference contour (e.g., are there larger differences in the center of the domain compared to the edges)? If so, explain why differences are not uniform across the entire domain. Based on your engineering judgment, is your numerical solution accurate (explain why or why not)? What can be done to improve the accuracy of your numerical solution? [4-6 sentences]

2a. The average difference between the measured and computed temperatures spatially over the entire domain was 1.07% difference. Regions in the domain where the differences are greater than the average are near the edges of the heating areas. The maximum percent difference in the domain was 4.09% at x = 14.68 cm and y = 0.41 cm. There is a trend observed in the percent difference countour where the regions of heating (i.e the left and right edges) display higher percent difference than the rest of the plate. This is because the numerical simulation has a bigger difference in the temperature points around the edges which results in greater numerical averages for the surrounding points as opposed to the small temperature point gradients towards the center which yields better averages. The numerical solution is accurate due to the small percent difference across the domain between the numerical and measured temperatures. Accuracy can be improved by improving boundary condition temperate discretization by adding more data points which will refine the resolution of the numerical simulation.

2b. How uniform are the temperatures along the left, top, and right edges? Quantify your answer in terms of a percentage based on the ratio of the standard deviation over the mean, i.e.,

$$2\,\frac{\sigma_T}{\overline{T}} \cdot 100\%$$

for each edge, where σ_T denotes the standard deviation along the edge and $\overline{T}$ denotes the average value along the edge. Note, the factor of 2 is used, because a spread of 2 standard deviations in a normal (Gaussian) probability density distribution captures 95% of the entire distribution, and thus yields a good measure of how far the measurements deviate from the average. Based on your engineering judgment, would it have been appropriate to assume a uniform temperature distribution along the left, top, and right boundaries in your numerical model (explain why or why not)? Does the measured temperature data along the bottom edge indicate that an adiabatic condition is appropriate for the numerical model (justify your answer)? [4 sentences]

2b. The left, top, and right edge temperatures are 10.45% non-uniform, 8.49% non-uniform, and 15.87% non-unform respectively. It is appropriate to assume a uniform temperature distribution along the left, top, and right boundaries due to the small percentage of non-uniformity across the edge domains. The measured temperature data along the bottom edge does indicate an adiabatic condition due to a 10.98% non-uniformity between measurements where we would expect to see high uniformity in the case of an adiabatic condition.

2c. Based on your q calculations from Table 1e, estimate how much total power was required to heat/cool the boundaries of the plate in Watts. Assume that the TECs are 15% efficient in cooling mode and 95% efficient in heating mode, which are typical values specified for these types of devices. Compare these calculations to the actual measured electrical power supplied to the TECs. Explain any discrepancies between the two. [3-4 sentences, plus equations as appropriate]

2c. The total estimated wattage to heat and cool the plate was 307 watts while the actual total power supplied was 431 watts. The left edge estimated power requirement to heat the plate was 130 watts based a 95% efficiency heating mode where the actual measured electrical power for this edge was 323 watts. The right edge estimated power requirement to heat the plate was 91 watts based on 95% efficiency heating mode where the actual measured electrical power for this edge was 55.8 watts. The difference in the heating estimated power requirements and the actual supplied power can be explained by the experimental setup where the data was taken during the transient response and not the steady state which didn't allow the electrically supplied power to fully saturate the system. The top edge of the plate had an estimated power requirement of 94 watts to cool the edge based on a 15% efficiency where the actual measured electrical power was 54 watts. This discrepancy can be explained by other forms of heat transfer on the top plate other than conduction. Radiation and convection could also cool the top of the plate which would reduce the power requirement to achieve the measured data.