Flat Plate Convection Lab

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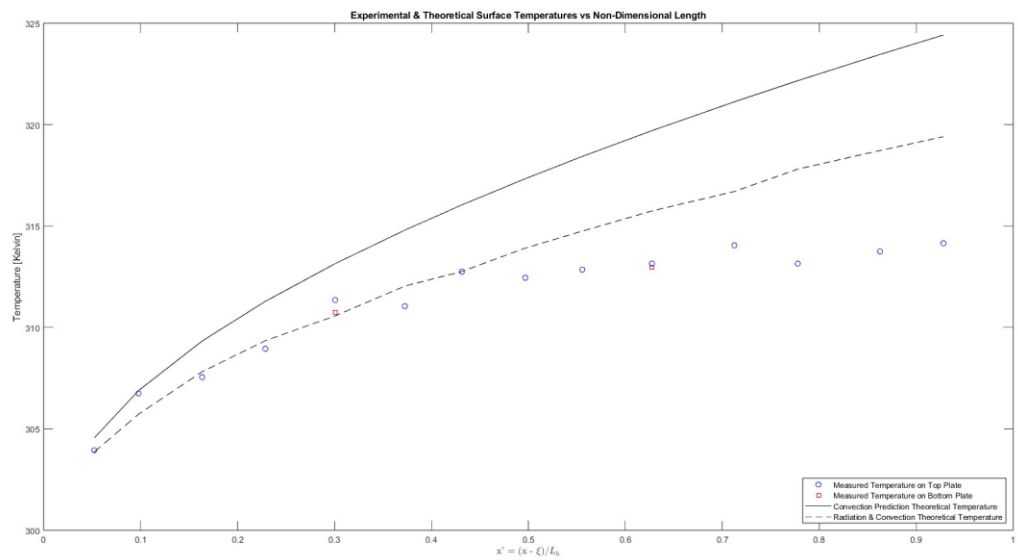

Figure 1a. Plot of the experimentally and theoretically calculated surface temperature on the y-axis in kelvin versus non dimensional length on the x-axis. The blue circles represent measured surface temperature values on the top of the plate, red squares represent measured surface temperature values on the bottom of the plate, the solid black line represents theoretical surface temperatures on the top of the plate only accounting for convection, and the dashed black line represents theoretical surface temperatures on the top of the plate accounting for convection and radiation.

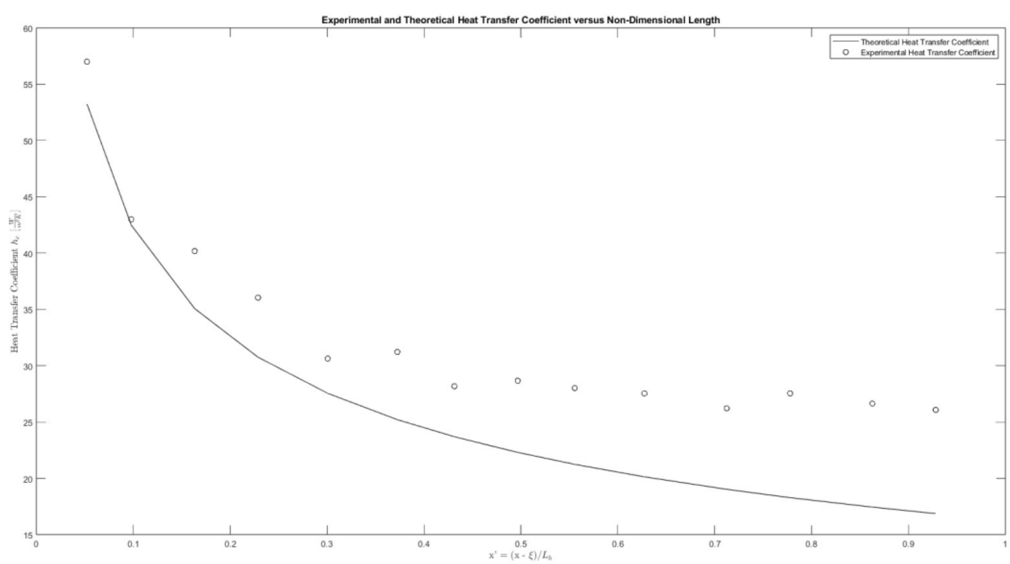

Figure 1b. Plot of experimental and theoretical local heat transfer coefficient on the y-axis in watts per square meter kelvin versus non dimensional length on the x-axis. The black line represents the theoretical local heat transfer coefficient while the black circles represent the experimental local heat transfer coefficient.

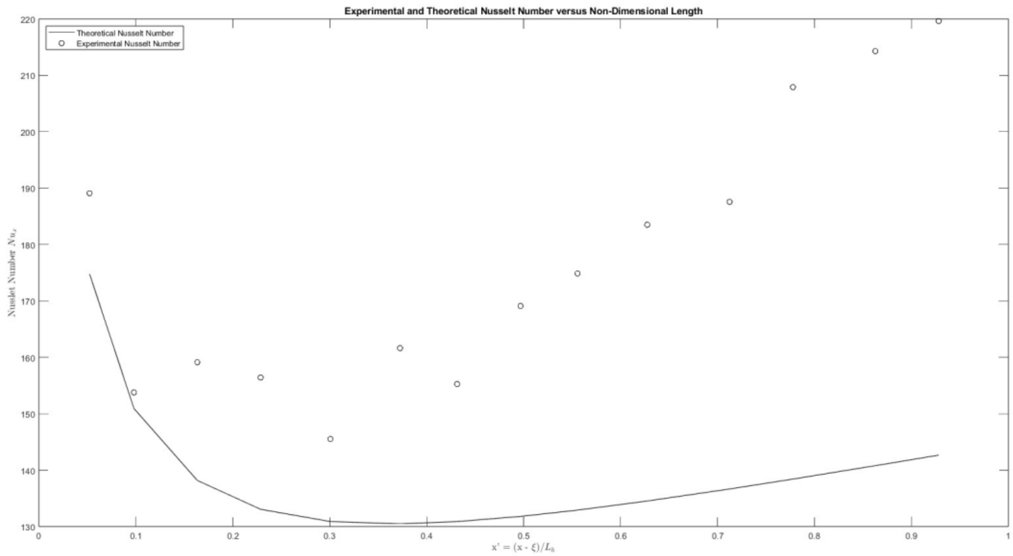

Figure 1c. Plot of experimental and theoretical local Nusselt number on the y-axis versus non dimensional length on the x-axis. The solid black line represents the theoretical local Nusselt number and the black circles represent the experimental local Nusselt number.

Table 1d. Measured and theoreretical values for the average Nusselt number, average heat transfer coefficient in watts per square meter kelvin, and net heat transfer rate in watts on the top surface of the plate.

	$\overline{Nu}_L$	$\bar{h}_L$ (W/m^{2}K)	q_s (W)
Measured	340.89	38.37	5.01
Theoretical	243.67	27.43	4.026

Short-Answer Questions

2a. Calculate the percent difference between the theoretical and experimental values of Nu_x, h_x, and T_s as a function of x',

$$\epsilon_Y = \frac{Y_{\text{exp}} - Y_{\text{th}}}{Y_{\text{th}}} \cdot 100,$$

where Y denotes the quantity of interest. State the ranges of ϵ_Y (min & max percentage values) for each quantity (Nu_x, h_x, and T_s). Describe the trend in ϵ_Y with x', and comment whether there are regions along the plate (in terms of x') where the agreement between theory and experiment are more/less favorable for each quantity. [2–4 sentences]

2a. The range for percent difference of the local Nusselt number, convection heat transfer coefficient and surface temperature accounting for radiation and convection is [1.8%, 53.95%], [1.25%, 54.62%], and [0.33%,1.65%] respectively. For the local Nusselt number, the data shows that the the first two non-dimensional lengths correspond to relatively low percent difference while increasing the non-dimensional length increases the percent difference where it hits its max at the trailing edge of the plate which implies that the agreement between theory and experiment is more favorable at the leading edge. For the local heat transfer coefficient, the percennt difference is relatively uniform for the first 5 non-dimensional length and then the percent difference begins to increase and reach a max at the trailing edge of the plate which implies that theory and experiment agree early in the non-dimensional length but become more inaccurate about a third of the way through the plate. For surface temperature, data shows that the theoretical percent difference from the experimental values is relatively low throughout the entire non-dimensional length when considering both convection and raditation.

2b. State the percent difference between the experimental and theoretical values for the average heat transfer coefficient and average Nusselt number based on the values given in your table from 1d. When calculating the percent difference, use the same form of the equation as given above for 2a. Offer a viable explanation as to why these differences are so high, and suggest one modification to the experiment or data analysis methods that might lead to better agreement. [3–4 sentences]

2b. The average percent difference in the Nusselt number and heat transfer coefficient based on the values from table 1d are 39.9% and 39.8% respectively. A major reason why the percent difference between experimental and theoretical values is due to the calculation of the theoretical values. This is due to the fact that both the Nusselt number and heat transfer coefficient us the local Reynolds number which was calculated using an approximate kinematic viscosity found using an average film temperature rather than the actual fluid temperature. To improve the data analysis to lead to better agreement, the experiment could be modified to collect the fluid temperatures at the non-dimensional lengths to improve Reynolds number calculations and therefor improved Nusselt and heat transfer coefficients.

2c. State the percentage contribution of heat flux lost to the surroundings via radiation compared to the net heat flux to the top surface by the resistive heaters,

$$\frac{q''_{\mathrm{rad},L}}{q''_s} \cdot 100,$$

where q''_s is the net heat flux to the top surface based on the power supply measurements as given in equation (12) of the Handout, and $q''_{\mathrm{rad},L}$ is the average radiation flux as given in equation (28) of the Handout. Does radiation heat transfer help to explain any discrepancies that are observed between the experimental and theoretical data? Explain why or why not. [2–3 sentences]

2c. The percentage contribution of the heat flux lost to the surroundings via radiation compared to the net heat flux to the top surface by the resistive heaters is 14.31%. The radiation heat transfer does help to explain discrepancies between experimental and theoretical data where the max percent difference between theoretical and experimental surface temperatures due to convection only was 3.17% while it was 1.64% due to convection and radiation. This difference is due to the assumption of heat transfer in only one form which cools the surface temperature when in reality there are multiple forms of heat transfer working to cool the surface tmeprature.

2d. State the Reynolds number (based on L) for the flow over the heated surface, where L is measured from the leading edge to the end of the heated surface. Comment on whether the boundary layer is expected to be laminar over the entire heated surface. Comment on how you could verify (experimentally) that the boundary layer is indeed laminar or turbulent. [2–3 sentences]

2d. The Reynolds number based on the flow over the entire heatred surface was 85784. The boundary layer is expected to be laminar over the entire heated surface as it does not reach the critical Reynolds number for laminar to turbulent transition which is 500000 for external flow. The way that we could verify that the boundary layer is laminar is to use flow visualization methods like smoked streamlines and observe the streamline behavior over the plate.