Lab 9: Flat Plate Convection

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4/3/2020

1. Figure and Tables

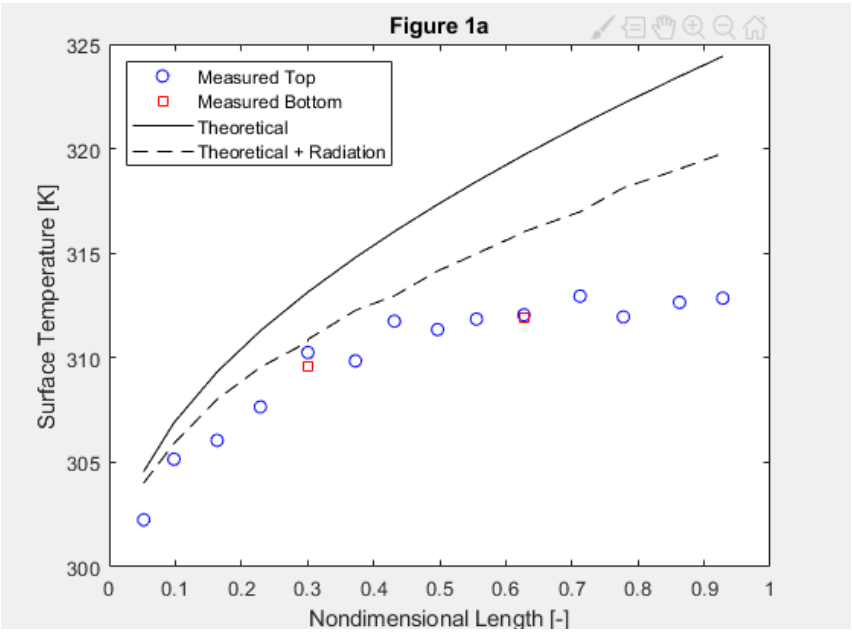


Figure 1a. Plot of surface temperature T_S in units of K versus the nondimensional length x', comparing measured data with theoretical calculations

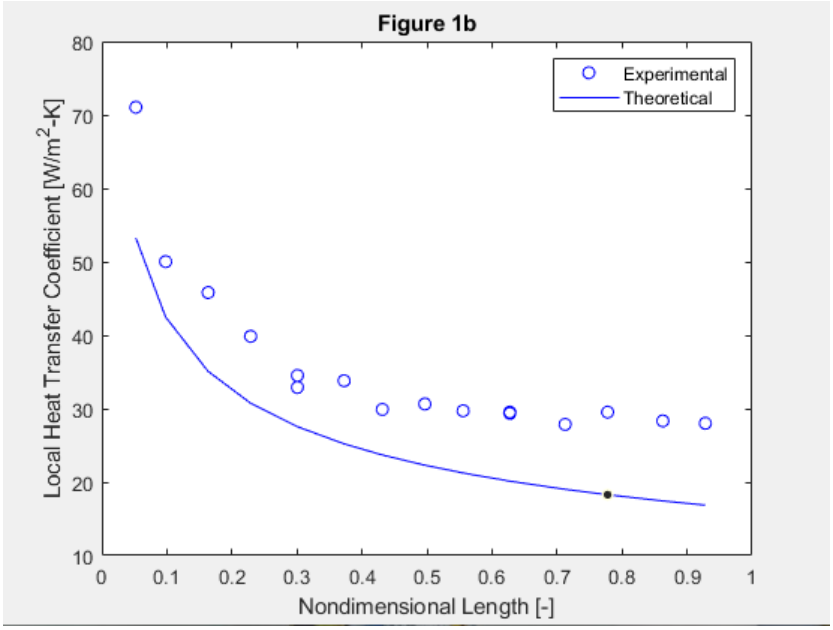


Figure 1b. Plot of the local heat transfer coefficient h in units of [W/m^2-K] versys the nondimensional length x', comparing measured data with theoretical calculations

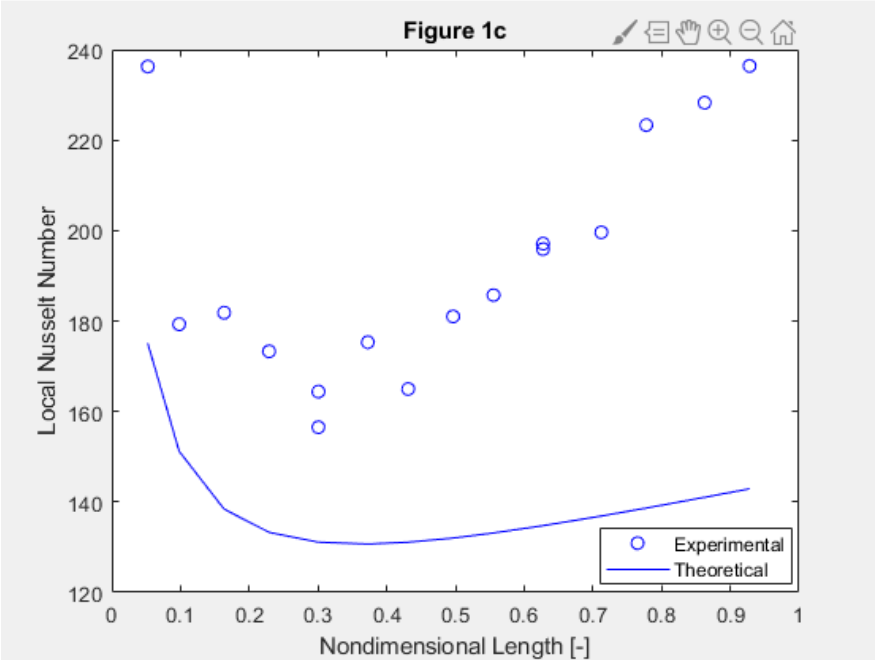


Figure 1c. Plot of the local Nusselt Number versus the nondimensional length x'

Table 1d. Table of average Nusselt number $\overline{Nu_L}$, average heat transfer coefficient $\overline{h_L}$, and heat transfer rate q_s

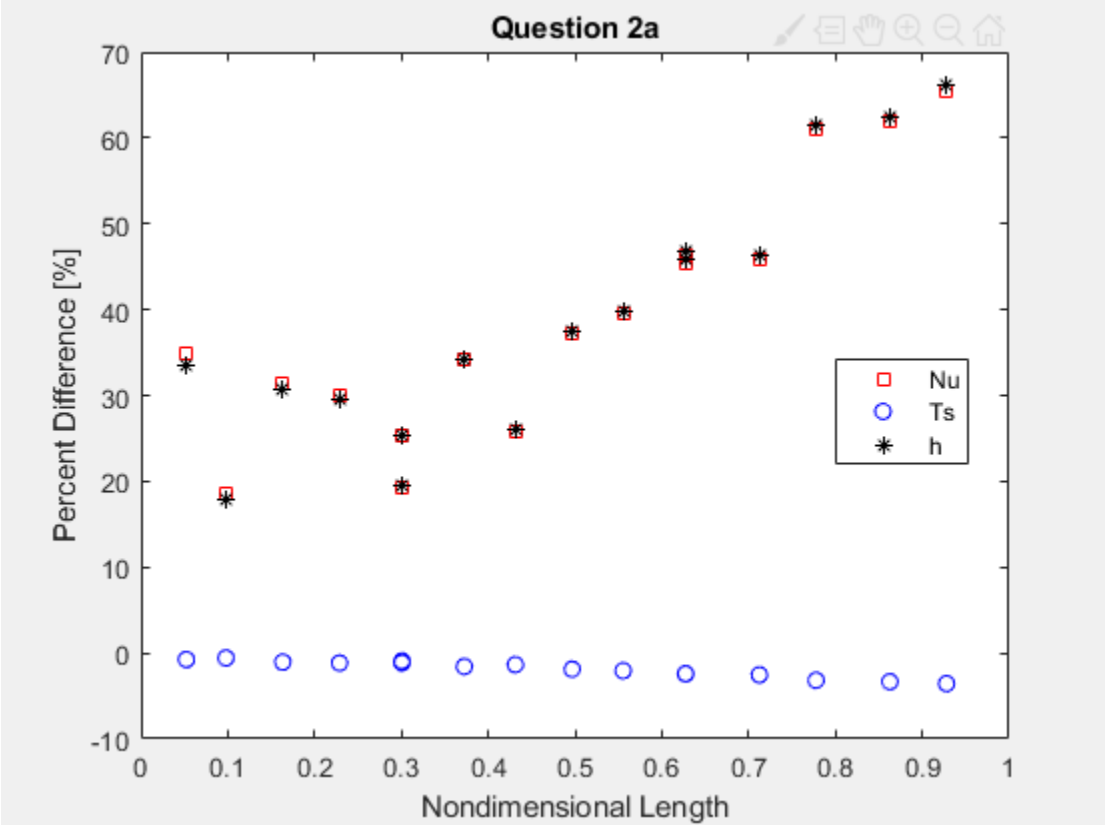
	$\overline{Nu_L}$	$\overline{h_L}$ (W/m^2-K)	q_s (W)
Measured	372.92	32.45	4.81
Theoretical	244.08	27.43	5.09

2. Short Answer Questions

a) *Calculate the percent difference between the theoretical and experimental values of Nux, hx, and Ts as a function of x 0 ,*

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

where Y denotes the quantity of interest. State the ranges of Y (min & max percentage values) for each quantity (Nux, hx, and Ts). Describe the trend in Y with x 0 , and comment whether there are regions along the plate (in terms of x 0) where the agreement between theory and experiment are more/less favorable for each quantity. [2–4 sentences]



Based on the plot above, the error between the measured and theoretical values for the Nusselt number and the heat transfer coefficient increases as the nondimensional length increases. The error between the measured and theoretical surface temperatures, however, is almost non-existent (~1 – 2%). For the heat transfer coefficient and the Nusselt number, the error is lower at thermocouples 2 and 6.

b) *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].*

The percent difference between the experimental and theoretical values for the average heat transfer coefficient is 18.32% while the precent difference between the experimental and theoretical values for the average Nusselt number is 52.79%.

One reason why that the percent differences for both values are so high is because the air properties used to calculate Re and Pr are assumed to be constant, calculated at the average film temperature. To remedy this, Re and Pr should be calculated at the local film temperature.

c) *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,*

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

where q 00 s is the net heat flux to the top surface based on the power supply measurements as given in (12), and q 00 rad,L is the average radiation flux as given in (28). 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].

The percentage contribution of heat flux lost to the surroundings via radiation is 12.70%. Radiation heat transfer does explain the discrepancies observed between the experimental and theoretical data. As shown in Figure 1a, the difference between the theoretical surface temperatures corrected by radiation and the measured surface temperatures is smaller than than the difference between the uncorrected theoretical and measured surface temperatures.

d) *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]*

The Reynolds number (based on L) for the flow over the heated surface is 8.596×10^4. For a flat surface, the critical Reynold's number is 5×10^5. Since the Reynolds number is lower than the critical Reynold's number, the boundary layer is expected to be laminar over the entire heated surface.