Heat Exchanger Lab

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Table 1a. Characteristics table of the shell and tube heat exchanger experiment. The three left columns show different cases of hot and cold fluid flow rates in kilograms per second while the top row shows heat exchanger characteristics in SI units such as fluid temperature difference in degrees Celsius, overall heat transfer coefficient in watter per meter squared kelvin, and heat transfer rates in watts.

Case	Flow Rate (kg/s)		Temperature (°C)		U_i (W/Km^2)	Heat Transfer Rate (kW)		
	$\dot{m}_c$	$\dot{m}_h$	ΔT_h	ΔT_c		q_c	q_h	$\Delta q(\%)$
1a	0.2395	0.2876	5.1667	6.7778	1973.45	6.8035	6.2106	9.1111
1b	0.2332	0.1875	7.000	6.7778	1738.28	6.6250	5.4878	18.7762
2a	0.2017	0.3250	4.000	7.1667	1705.01	6.0579	5.4346	10.8474
2b	0.2143	0.1875	6.8889	7.0000	1684.43	6.2876	5.4000	15.1889

Table 1b. Characteristics table of the shell and tube heat exchanger experiment. The three left columns show different cases of hot and cold fluid flow rates in kilograms per second while the top row shows heat exchanger characteristics in SI units such as heat capacities, non-dimensional number of transfer units, and heat transfer effectiveness.

Case	Flow Rate (kg/s)		C_r	NTU	ε		
	$\dot{m}_c$	$\dot{m}_h$			measured	Theory	$\Delta\varepsilon(\%)$
1a	0.2395	0.2876	0.8351	0.2157	0.1785	0.1800	0.8649
1b	0.2332	0.1875	0.8021	0.2432	0.1963	0.1995	1.6157
2a	0.2017	0.3250	0.6222	0.2213	0.1855	0.1875	1.0977
2b	0.2143	0.1875	0.8727	0.2357	0.1905	0.1931	1.3602

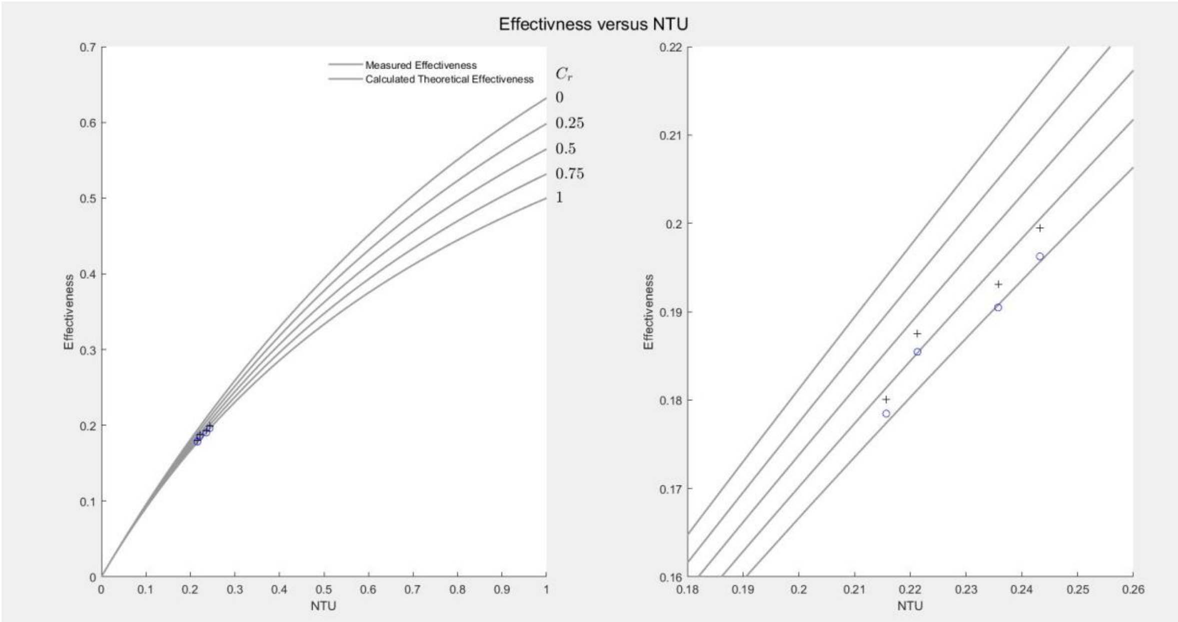

Figure 1c. Zoomed out plot of theoretical curves of effectiveness on the y-axis and number of transfer units on the x-axis (Left). The blue circles represent calculated measured effectiveness and the black crosses represent calculated theoretical effectiveness. Zoomed in plot of theoretical curves of effectiveness on the y-axis and number of transfer units on the x-axis (Right).

Short-Answer Questions

2a. Theoretically, we expect $q_h = q_c$. However, your measurements will not likely support this. In your analysis, you calculated the percent relative difference, Δq, between q_c and q_h. State the range of Δq calculated from your measurements. In addition, state the range of percent relative uncertainty in the calculated heat transfer rates: $(\sigma_{q_c}/q_c) \cdot 100\%$ and $(\sigma_{q_h}/q_h) \cdot 100\%$. State the extent to which the uncertainty in the measurements helps explain the observed difference between q_c and q_h? [3–4 sentences]

2a. The range of percent differences for the heat transfer is 9.11% to 18.78%. The range of percent uncertainty in the calculated heat transfer rates is 4.92% to 5.52% and 6.22% to 7.15% for the cold fluid heat transfer and hot fluid heat transfer respectively. Collectively, the uncertainty in the measurements helps to explain the observed difference between q_c and q_h because the max percent uncertainty for each respectively is 5.52% and 7.15%. This max difference leads to discrepancies in actual physical phenomena and our recorded data which can explain the discprepancy between the hot fluid heat transfer and the cold fluid heat transfer.

2b. State the percent difference in effectiveness values obtained from the measurements compared to theory ($\Delta\varepsilon$ in %). Based on your engineering judgment, does the theory adequately describe the observations? For example, is it possible to use the theory to predict the effectiveness of the present heat exchanger for the following case: $\dot{m}_c = 0.3$ kg/s and $\dot{m}_h = 0.4$ kg/s? If yes, explain how. If no, explain why not. [3–5 sentences]

The percent differences in effectiveness obtained in the measurements compared to theory are 0.86%, 1.62%, 1.10%, and 1.36% for flow case 1, case 2, case 3, and case 4 respectively. The theory does adequately describe the observations because of such a low percent difference between the values. It is possible to use theory to predict the effectiveness of flow rates of 0.3 kg/s for the cold fluid and 0.4kg/s for the hot fluid. This is because these flow rates are close to or within range of the experimental flow rates used to find the low percent difference in effectiveness. Therefor, we can reliably assume that these flow rates would have similar behavior to the experimental conclusions.

2c. Estimate the rate of heat transfer from the shell casing to the surroundings due to natural convection (q_{conv}) and radiation (q_{rad}). State the q_{conv} and q_{rad} values in kW averaged over all four test cases. Based on your engineering judgment, are these losses important and would you recommend insulating/covering the shell casing to mitigate these losses? Explain why or why not. Note, be sure to include your calculations for q_{conv} and q_{rad} in your computer code. [3–4 sentences]

2c. The estimated heat transfer to the surroundings due to convenction is 0.002465, 0.002599, 0.00266, and 0.00267 kilowatts for cases 1, 2, 3, and 4 respectively. The estimated heat transfer to the surroundings due to radiation is 0.003198, 0.003350, 0.003417, and 0.003427 kilowatts for cases 1, 2, 3, and 4 respectively. These losses are not important to the experiment and I would not recommend insulating/ convering the shell. This is because the heat transfer between the moving fluids are magnitudes greater than the heat transfer to the surroundings which means the effects of convection and radiation are negligible.