TFES Lab (ME EN 4650)
Shell and Tube Heat Exchanger

Required Figures/Tables

Captions

A meaningful and comprehensive caption must accompany all figures and tables. For the two tables, the caption is placed *above* the table and includes the label Figure 1x., where x denotes the letter a–b according to the plot order listed below. For the figure, the caption is placed *below* the figure and includes the label Figure 1c.

Plots and Tables

1a. Create a table that looks like the one below, inserting the values from your analysis in each of the shaded boxes. Note, for cases 1a & 1b, the cold-side flow rate $\dot{m}_c$ is relatively fast. While, for cases 2a & 2b, the cold-side flow rate is relatively slow, approximately half that of cases 1a & 1b. The temperature differences between the inlet and outlet are $\Delta T_c = T_{c,o} - T_{c,i}$ and $\Delta T_h = T_{h,i} - T_{h,o}$. The heat transfer rates q_c and q_h are calculated based on equations (3) and (2) from the Handout, respectively. Finally, the percent difference in the hot-side and cold-side heat transfer rates (Δq) is quantified using the following expression

$$\Delta q = \frac{|q_h - q_c|}{\frac{1}{2}(q_h + q_c)} \cdot 100\% \,. \tag{1}$$

Case	Flow Rate (kg/s)		Temperature (°C)		U_i	Heat Transfer Rate (kW)		
	$\dot{m}_c$	$\dot{m}_h$	ΔT_h	ΔT_c	(W/K m^2)	q_c	q_h	Δq (%)
1a	(fast)	(fast)						
1b	(fast)	(slow)						
2a	(slow)	(fast)						
2b	(slow)	(slow)						

1b. Create a table that looks like the one below, inserting the values from your analysis in each of the shaded boxes. Values of the measured effectiveness, ε, are calculated from equation (7) of the Handout; while, values of the theoretical effectiveness, $\varepsilon_{\text{theory}}$, are calculated from equation (12) of the Handout. The percent relative difference between the measured and theoretical effectiveness is calculated using the following expression

$$\Delta\varepsilon = \frac{|\varepsilon - \varepsilon_{\text{theory}}|}{\varepsilon_{\text{theory}}} \cdot 100\% \,. \tag{2}$$

Case	Flow Rate (kg/s)		C_r	NTU	ε		
	$\dot{m}_c$	$\dot{m}_h$			measured	theory	Δε (%)
1a	(fast)	(fast)					
1b	(fast)	(slow)					
2a	(slow)	(fast)					
2b	(slow)	(slow)					

1c. Download the Matlab file for Figure 5 of the Handout (EffectivenessNTUFigure.fig) that shows theoretical curves of ε versus NTU over a range of C_r values for a single tube-pass, single-shell pass counterflow heat exchanger. On this same figure, plot ε calculated from equation (7) of the Handout based on your measurements using ○ markers. Also on this same figure, plot $\varepsilon_{\text{theory}}$ calculated from equation (12) of the Handout using + markers.

Create two subplots placed side-by-side. The left subplot should be the same plot as generated above and should contain a legend. The right subplot should be zoomed-in near the cluster of data to highlight the discrepancy between the measurements and theory. Use the following axis limits:

(i) Left subplot: $0 \leq \varepsilon \leq 0.7$ and $0 \leq NTU \leq 1$.

(ii) Right subplot: $0.16 \leq \varepsilon \leq 0.22$ and $0.18 \leq NTU \leq 0.26$

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]

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]

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]