Heat and Mass Transfer (DI05019071)

Complete Lecture Deck

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July 23, 2026

Effectiveness of Heat Exchanger: Applications

- Course: Heat and Mass Transfer (DI05019071)
- Unit 4: Heat Exchanger
- Lecture 36: Applying the NTU Method

Lecture Agenda

- 1. Reading Effectiveness-NTU Charts
- 2. Special Case: Phase Change ($c = 0$)
- 3. Special Case: Balanced Flow ($c = 1$)
- 4. Step-by-Step: Performance Problems
- 5. Step-by-Step: Design/Sizing Problems
- 6. Unit 4 Summary

Effectiveness-NTU Charts

- Instead of complex formulas, engineers often use charts.
- X-axis: NTU (Number of Transfer Units)
- Y-axis: Effectiveness (ε, from 0 to 1 or 0 to 100%)
- Curves: Different values of capacity ratio 'c' (from 0 to 1).

Chart Observations

- For a given NTU and given flow type, effectiveness increases as 'c' decreases.
- Maximum effectiveness always occurs at c = 0.
- For NTU ¿ 3, the curves flatten out.
- Increasing NTU (making the exchanger larger/more expensive) yields diminishing returns in performance.

Special Case: Phase Change (c = 0)

- For condensers and evaporators, C_max = infinity, so c = 0.
- Looking at the formulas or charts, the flow arrangement (parallel vs counter) disappears from the math.
- ε = 1 - exp(-NTU) (for all flow arrangements!)
- This perfectly matches our conclusion from the LMTD method.

Special Case: Balanced Flow ($c = 1$)

- If C_min = C_max, then $c = 1$.
- Example: Gas-to-gas heat recovery with equal flow rates.
- Parallel Flow: ε = 0.5 * [1 - exp(-2*NTU)] (Max ε = 50%)
- Counter Flow: ε = NTU / (1 + NTU) (Max ε approaches 100%)
- This proves counter flow is vastly superior for balanced flows.

Solving Performance Problems

- Goal: Find outlet temps when Area (A) is given.
- 1. Calculate C_h, C_c. Determine C_{min}, C_{max}, and c.
- 2. Calculate NTU = UA / C_{min}.
- 3. Find ε using formulas or charts.
- 4. Calculate $q_{max} = C_{min} * (T_{h,in} - T_{c,in})$.
- 5. Calculate actual $q = \varepsilon * q_{max}$.
- 6. Calculate $T_{h,out}$ and $T_{c,out}$ using q.

Solving Design (Sizing) Problems

- Goal: Find Area (A) when inlet and outlet temps are known.
- 1. Calculate C_h, C_c. Determine C_{min}, C_{max}, and c.
- 2. Calculate actual q, and q_{max}.
- 3. Calculate required $\varepsilon = q / q_{max}$.
- 4. Find required NTU using charts (or inverted formulas).
- 5. Calculate Area = (NTU * C_{min}) / U.

Example Problem: Performance

- A counter-flow exchanger has U = 200 W/m^2K, A = 10 m^2.
- Hot water: 2 kg/s, cp=4180 J/kgK, inlet = 90°C.
- Cold water: 1 kg/s, cp=4180 J/kgK, inlet = 20°C.
- Step 1: Ch = 8360 W/K. Cc = 4180 W/K. C_min = Cc = 4180.
- Step 2: c = 4180/8360 = 0.5.

Example Problem: Solution

- Step 3: NTU = UA/C_min = (200*10)/4180 = 0.478.
- Step 4: Use chart or formula for Counter flow (NTU=0.478, c=0.5) -¿ $\varepsilon \approx 0.35$
- Step 5: q_max = 4180 * (90 - 20) = 292,600 W
- Step 6: q_actual = 0.35 * 292,600 = 102,410 W
- Step 7: Tc,out = 20 + 102,410/4180 = 44.5°C

Choosing Between Methods

- When to use LMTD:
- - Sizing a new heat exchanger (finding Area).
- - All inlet and outlet temperatures are known or easily found.
- When to use Effectiveness-NTU:
- - Evaluating an existing heat exchanger.
- - Finding outlet temperatures.
- - Comparing different heat exchanger designs (ε is a great metric).

Unit 4 Summary

- Unit 4 covered the analysis of heat exchangers.
- We learned basic classifications (parallel, counter, cross flow).
- We defined the Overall Heat Transfer Coefficient (U) and fouling.
- We derived and applied the LMTD method.
- We defined Effectiveness, NTU, and applied the NTU method.

Next Unit Preview

- Unit 5: Mass Transfer
- We will move away from moving heat, and look at moving mass.
- Topics will include Fick's Law of Diffusion, concentration gradients, and modes of mass transfer.
- Prepare by reviewing concentration definitions (molarity, mass fraction).