Heat and Mass Transfer (DI05019071)

Complete Lecture Deck

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July 23, 2026

Effectiveness of Heat Exchanger (NTU Method)

- Course: Heat and Mass Transfer (DI05019071)
- Unit 4: Heat Exchanger
- Lecture 31: Effectiveness - NTU Method

Lecture Agenda

- 1. Limitations of the LMTD Method
- 2. The NTU Method Overview
- 3. Maximum Possible Heat Transfer (Q_max)
- 4. Heat Exchanger Effectiveness (Epsilon)
- 5. Number of Transfer Units (NTU)
- 6. Epsilon-NTU Relations

Limitations of the LMTD Method

- LMTD is easy to use if all inlet and outlet temperatures are known (Design problems).
- If only the inlet temperatures are known, outlet temperatures must be guessed and iterated.
- Performance evaluation problems (finding Q for a given exchanger) are tedious with LMTD.
- Need a method that avoids iteration.

The Effectiveness-NTU Method

- Developed by Kays and London in 1955.
- Predicts the outlet temperatures and heat transfer rate without iteration.
- Based on a dimensionless parameter called heat exchanger effectiveness (epsilon).
- Highly preferred for performance evaluation of existing heat exchangers.

Determining C_min and C_max

- Recall heat capacity rates: $C_h = m_h * c_{ph}$ and $C_c = m_c * c_{pc}$.
- Compare C_h and C_c.
- The smaller value is designated as C_{min}.
- The larger value is designated as C_{max}.
- The fluid with C_{min} will experience the largest temperature change.

Maximum Possible Heat Transfer (Q_{max})

- What is the maximum heat transfer theoretically possible?
- It occurs in a very long counter-flow heat exchanger.
- The fluid with C_{min} would reach the inlet temperature of the other fluid.
- $Q_{max} = C_{min} * (T_{h,in} - T_{c,in})$

Heat Exchanger Effectiveness

- Effectiveness (epsilon) = Actual heat transfer rate / Maximum possible heat transfer rate
- epsilon = Q / Q_max
- Since Q = C_c(T_c,out - T_c,in) = C_h(T_h,in - T_h,out)
- epsilon is a dimensionless number between 0 and 1.

Number of Transfer Units (NTU)

- NTU is a dimensionless parameter widely used for heat exchanger analysis.
- NTU = (U * A) / C_min
- It is a measure of the heat transfer surface area (A).
- A larger NTU means a physically larger heat exchanger.

Capacity Ratio (c)

- Another dimensionless parameter is the capacity ratio, c.
- $c = C_{min} / C_{max}$
- c ranges from 0 to 1.
- For phase change (boiling or condensation), C_{max} approaches infinity, so $c = 0$.

Effectiveness Relations: Parallel Flow

- Effectiveness can be expressed as a function of NTU and c: epsilon = f(NTU, c)
- For Parallel Flow:
- epsilon = [1 - exp(-NTU(1+c))] / (1+c)
- Charts are available to look up epsilon based on NTU and c.

Effectiveness Relations: Counter Flow

- For Counter Flow (when c ¡ 1):
- epsilon = [1 - exp(-NTU(1-c))] / [1 - c*exp(-NTU(1-c))]
- If c = 1 ($C_{min} = C_{max}$): epsilon = NTU / (1 + NTU)
- Counter flow charts show higher effectiveness for the same NTU.

Summary

- The NTU method eliminates iteration when outlet temperatures are unknown.
- Effectiveness (epsilon) compares actual heat transfer to theoretical maximum.
- NTU = UA / C_min is a dimensionless measure of size.
- Effectiveness charts map epsilon, NTU, and c.

Next Lecture Preview

- Topic: Advanced Heat Exchanger Concepts
- - Concept of heat pipe
- - Compact heat exchanger design
- - Specialized applications