Heat and Mass Transfer (DI05019071)

Complete Lecture Deck

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Heat Exchanger Analysis

- Course: Heat and Mass Transfer (DI05019071)
- Unit 4: Heat Exchanger
- Lecture 28: Heat Exchanger Analysis

Lecture Agenda

- 1. Goals of Heat Exchanger Analysis
- 2. Overall Energy Balance
- 3. Heat Transfer Rate Equations
- 4. Key Assumptions in Analysis
- 5. Heat Capacity Rates
- 6. Need for Mean Temperature Difference

Goals of Heat Exchanger Analysis

- Analysis typically involves two types of problems:
- 1. Performance evaluation: Determining the heat transfer rate and fluid outlet temperatures for an existing heat exchanger.
- 2. Design problem: Determining the required surface area to achieve specific outlet temperatures given flow rates and inlet temperatures.

Overall Energy Balance

- Based on the First Law of Thermodynamics (Conservation of Energy).
- In a steady-flow device, the rate of heat transfer from the hot fluid equals the rate of heat transfer to the cold fluid.
- Q_hot_rejected = Q_cold_absorbed (assuming no heat loss to surroundings).

Heat Transfer Rate Equations

- For the hot fluid: Q = m_h * c_ph * (T_hi - T_ho)
- For the cold fluid: Q = m_c * c_pc * (T_co - T_ci)
- Where: m = mass flow rate, c_p = specific heat, T_i = inlet temp, T_o = outlet temp.

Key Assumptions in Analysis

- 1. Steady-flow operating conditions.
- 2. Kinetic and potential energy changes are negligible.
- 3. Specific heats of fluids remain constant.
- 4. Axial heat conduction along the tubes is negligible.
- 5. The outer surface of the heat exchanger is perfectly insulated (no heat loss).

Temperature Profiles

- Temperature of fluids changes continuously as they flow through the exchanger.
- The driving force for heat transfer is the temperature difference (T_h - T_c) at any location.
- This local difference varies along the length of the exchanger.

Heat Capacity Rates

- A useful parameter is the heat capacity rate, C.
- Defined as the product of mass flow rate and specific heat.
- C_h = m_h * c_ph (for hot fluid)
- C_c = m_c * c_pc (for cold fluid)
- Equations become: Q = C_h * (T_hi - T_ho) = C_c * (T_co - T_ci)

Phase Change Considerations

- If a fluid undergoes a phase change (like boiling or condensation), its temperature remains constant.
- In this case, the heat transfer rate is Q = m * h_fg
- Where h_fg is the latent heat of vaporization or condensation.
- The heat capacity rate C approaches infinity during phase change.

Newton's Law of Cooling in HE

- Locally, heat transfer rate is expressed as: dQ = U * dA * (T_h - T_c)
- Where U is the overall heat transfer coefficient.
- dA is a differential surface area.
- T_h and T_c are local temperatures.

Need for Mean Temperature Difference

- Integrating dQ = U * dA * delta_T gives Q = U * A * delta_T_mean
- Since delta_T varies along the length, we cannot use a simple arithmetic average.
- We require a properly weighted average temperature difference to calculate total Q accurately.

Summary

- Energy balances allow us to relate heat transfer to fluid temperature changes.
- Q = C_h * delta_T_h = C_c * delta_T_c
- Assumptions like steady-state and zero heat loss simplify analysis.
- A mean temperature difference is required to use Q = U * A * delta_T_m.

Next Lecture Preview

- Topic: Log Mean Temperature Difference (LMTD)
- - Derivation of LMTD for parallel flow
- - Derivation of LMTD for counter flow
- - Application to condensers and evaporators