Heat and Mass Transfer (DI05019071)

Complete Lecture Deck

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Log Mean Temperature Difference (LMTD)

- Course: Heat and Mass Transfer (DI05019071)
- Unit 4: Heat Exchanger
- Lecture 29: LMTD for Parallel, Counter Flow, Condenser & Evaporator

Lecture Agenda

- 1. The Concept of LMTD
- 2. Derivation of LMTD for Parallel Flow
- 3. Derivation of LMTD for Counter Flow
- 4. Comparing Parallel vs. Counter Flow
- 5. LMTD for Condensers
- 6. LMTD for Evaporators

The Concept of LMTD

- From Newton's Law of Cooling, total heat transfer Q = U * A * delta_T_m.
- delta_T_m must account for the non-linear temperature profiles of the fluids.
- By integrating the local heat transfer equations along the length, we obtain a logarithmic average.
- This is called the Log Mean Temperature Difference (LMTD).

Derivation Setup: Parallel Flow

- Consider a differential area dA in a parallel flow exchanger.
- Hot fluid temperature changes by dT_h (negative).
- Cold fluid temperature changes by dT_c (positive).
- Local temperature difference delta_T = T_h - T_c.

LMTD Parallel Flow Equation

- Integrating d(delta_T) / delta_T from inlet to outlet yields:
- LMTD = (delta_T_1 - delta_T_2) / ln(delta_T_1 / delta_T_2)
- Where for Parallel Flow:
- delta_T_1 = T_hi - T_ci (Inlet temperature difference)
- delta_T_2 = T_ho - T_co (Outlet temperature difference)

Derivation Setup: Counter Flow

- For counter flow, fluids move in opposite directions.
- Hot fluid enters at one end, cold fluid enters at the other.
- The derivation steps are similar, but the temperature boundary conditions change.

LMTD Counter Flow Equation

- The LMTD formula remains the same:
- LMTD = (delta_T_1 - delta_T_2) / ln(delta_T_1 / delta_T_2)
- However, the definitions change for Counter Flow:
- delta_T_1 = T_hi - T_co (Hot inlet minus Cold outlet)
- delta_T_2 = T_ho - T_ci (Hot outlet minus Cold inlet)

Comparing Parallel vs. Counter Flow

- For the same inlet and outlet temperatures, LMTD_counter ¿ LMTD_parallel.
- Since Q = U * A * LMTD, a larger LMTD means a smaller required surface area (A) for the same Q and U.
- Therefore, counter flow heat exchangers are more compact and economical.

Condensers in Heat Exchangers

- In a condenser, the hot fluid (vapor) condenses at a constant temperature (T_h = constant).
- The cold fluid absorbs heat and its temperature rises.
- Since T_h is constant, parallel and counter flow configurations yield the same temperature profile.

Evaporators in Heat Exchangers

- In an evaporator, the cold fluid (liquid) boils at a constant temperature (T_c = constant).
- The hot fluid rejects heat and its temperature drops.
- Similar to condensers, the flow direction (parallel vs counter) does not affect the LMTD.

LMTD for Phase Change

- For condensers and evaporators, use the standard LMTD formula.
- delta_T_1 and delta_T_2 are simply the temperature differences at the two ends.
- LMTD_parallel = LMTD_counter for any phase change exchanger where one temperature is constant.

Summary

- LMTD is the exact mean temperature difference for heat exchanger analysis.
- Counter flow LMTD is greater than parallel flow LMTD for the same conditions.
- Phase change devices have identical LMTD regardless of flow arrangement.

Next Lecture Preview

- Topic: Overall Heat Transfer Coefficient
- - Thermal resistance network in heat exchangers
- - Definition of U based on inner and outer areas
- - Fouling factors and their impact on performance