Heat and Mass Transfer (DI05019071)

Complete Lecture Deck

Milav Dabgar

Lecturer, GP Palanpur

July 23, 2026

Overall Heat Transfer Coefficient

- Course: Heat and Mass Transfer (DI05019071)
- Unit 1: Conduction
- Lecture 10: Overall heat transfer coefficient

Lecture Agenda

- 1. Introduction to Combined Modes
- 2. Defining the Overall Heat Transfer Coefficient (U)
- 3. U for a Plane Wall
- 4. U for a Cylindrical Surface
- 5. Inner vs. Outer Area Basis for U
- 6. Fouling Factors

Combined Modes of Heat Transfer

- Most engineering problems involve multiple modes of heat transfer.
- Example: Hot fluid inside a pipe, cold air outside.
- Heat transfers by: Convection (inside) -¿ Conduction (through pipe wall) -¿ Convection (outside).
- We need a simple way to express this total process.

Defining the Overall Coefficient (U)

- We define the overall heat transfer coefficient, U, such that:
- q = U * A * ΔT_total
- Where ΔT_total is the temperature difference between the two bulk fluids.
- Comparing this to q = ΔT_total / R_total, we see that:
- U * A = 1 / R_total

U for a Plane Wall

- Consider a wall of thickness L, conductivity k, with fluids h_{in} and h_{out}.
- $R_{total} = (1/h_{in}*A) + (L/k*A) + (1/h_{out}*A)$
- Since area A is constant: $R_{total} = (1/A) * [1/h_{in} + L/k + 1/h_{out}]$
- Therefore: $1/U = 1/h_{in} + L/k + 1/h_{out}$

U for a Cylindrical Surface

- For a pipe, the inner area (A_in) is not equal to the outer area (A_out).
- R_total = 1/(h_in*A_in) + ln(r_out/r_in)/(2πLk) + 1/(h_out*A_out)
- Because area varies, U depends on which area we use as a reference.
- q = U_in * A_in * ΔT = U_out * A_out * ΔT

Inner vs. Outer Area Basis

- Based on inner area ($A\_in = 2\pi r\_in*L$):
- $1/U\_in = 1/h\_in + [r\_in * \ln(r\_out/r\_in)]/k + (r\_in/r\_out)*(1/h\_out)$
- Based on outer area ($A\_out = 2\pi r\_out*L$):
- $1/U\_out = (r\_out/r\_in)*(1/h\_in) + [r\_out * \ln(r\_out/r\_in)]/k + 1/h\_out$
- Note: $U\_in * A\_in = U\_out * A\_out$

Fouling Factor Concept

- Over time, surfaces accumulate deposits (rust, scale, algae).
- These deposits act as additional thermal resistance.
- We account for this using a 'fouling factor' (Rf).
- Rf has units of $m^2 \cdot K/W$.

Including Fouling in U

- We simply add the fouling resistances to our total resistance.
- $1/U = 1/h\_in + Rf\_in + L/k + Rf\_out + 1/h\_out$
- Fouling always decreases the overall heat transfer coefficient.
- Designers must overestimate U requirements to account for future fouling.

Typical Values of U (W/m^2K)

- Water to Water: 850 - 1700
- Water to Oil: 110 - 350
- Steam condenser (Water in tubes): 1000 - 6000
- Air to Water: 10 - 50
- Notice that systems involving gases (air) have much lower U values.

Example Problem

- A steel pipe (k=50) has r_in = 20 mm, r_out = 24 mm.
- Inside water h_in = 1000 W/m^{2}K. Outside air h_out = 15 W/m^{2}K.
- Calculate U based on the outside area (U_out).

Summary

- The overall heat transfer coefficient (U) combines conduction and convection.
- For cylinders, U must be referenced to a specific area (usually A_{in} or A_{out}).
- Fouling factors account for the thermal resistance of scale/dirt build-up.
- U simplifies the calculation of heat transfer in complex systems.

Next Lecture Preview

- Topic: Heat transfer from an extended surface (Fins)
- How can we increase heat transfer when convection is poor?
- We will explore the use of fins to increase surface area.