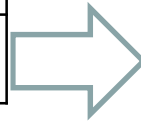


ME265: Thermal Engineering & Heat Transfer

Chapters
1. Energy Scenario
2. Thermodynamics
3. Mechanical Devices & Systems
4. Heat Transfer



4.1 Introduction	
4.2 Conduction	
4.3 Convection	
4.4 Radiation	4.4.1 Radiation Fundamentals 4.4.2 View factors/Shape factor 4.4.3 Radiation exchange between surfaces
4.5 Heat Exchanger	4.5.1 Fundamentals 4.5.2 Analysis: LMTD method

4.5 Heat Exchanger (HX)

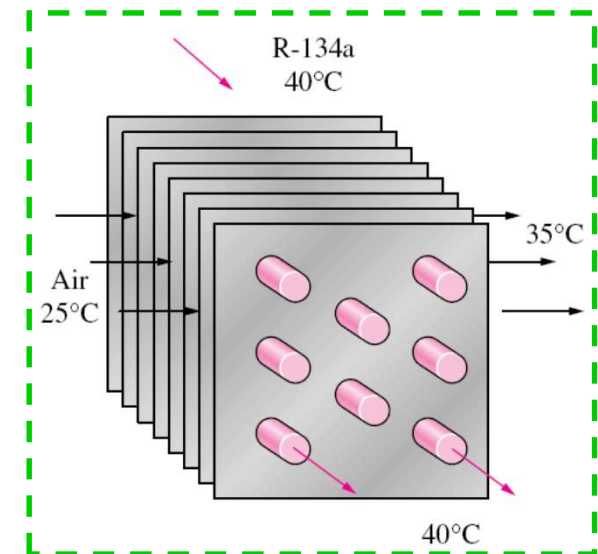
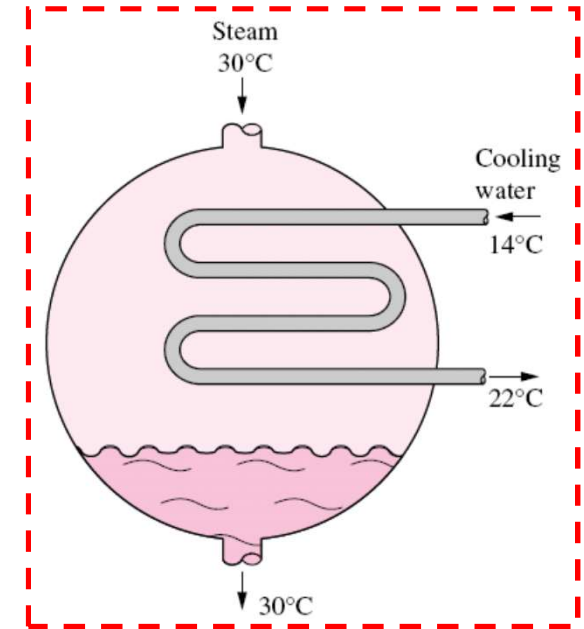
Objectives:

- Recognize different types of heat exchangers
- Develop an awareness of fouling on heat exchangers and determine overall heat transfer coefficient, U
- Obtain a relation for LMTD and use it for heat exchanger analysis
- Develop relations for effectiveness and analyse heat exchangers
- Know the primary considerations in the selection of heat exchangers

4.5 Heat Exchanger (HX)

□ HX Fundamentals

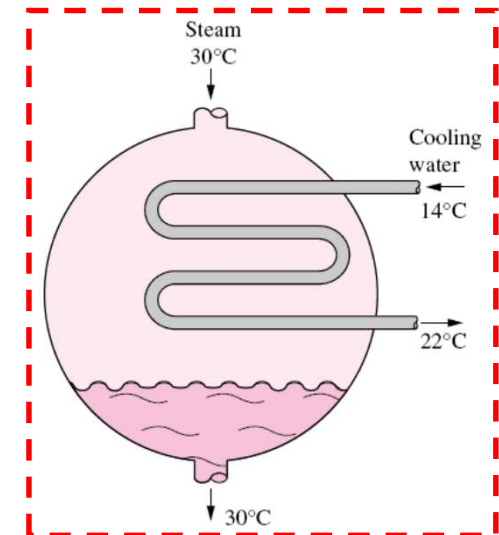
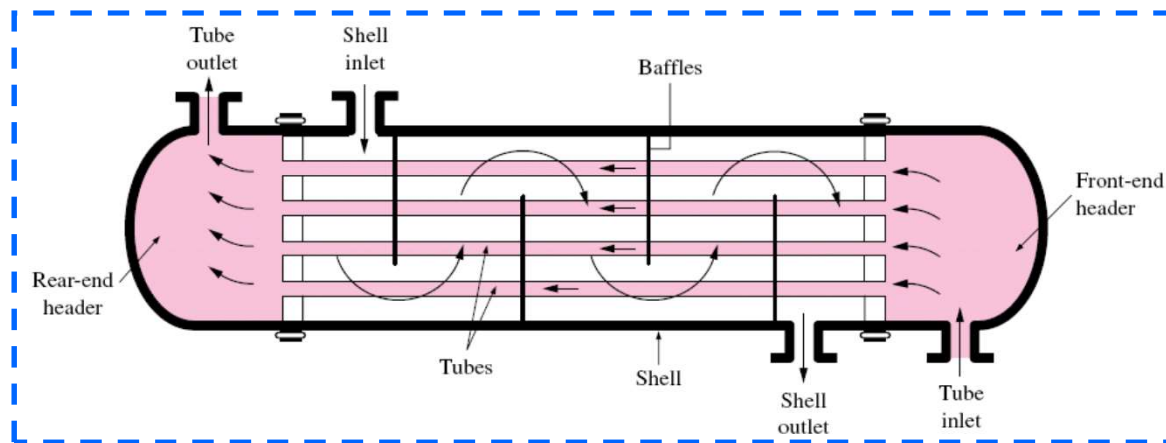
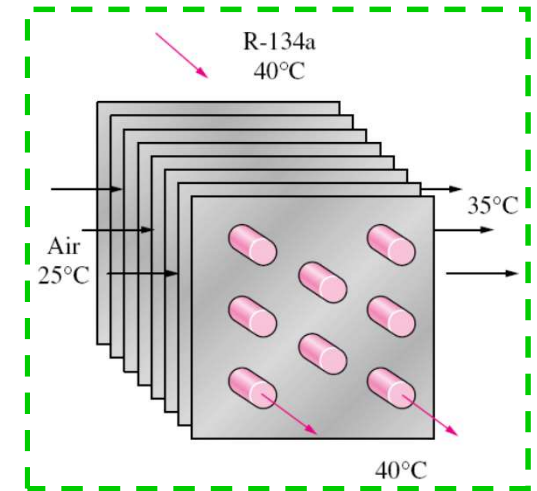
- Devices that facilitate the exchange of heat between two fluids keeping them apart from mixing with each other.
- Commonly used in wide ranges of applications: in heating, cooling, chemical processing, power production, etc.



MECE 371: 5.1 HX Fundamentals

Classification

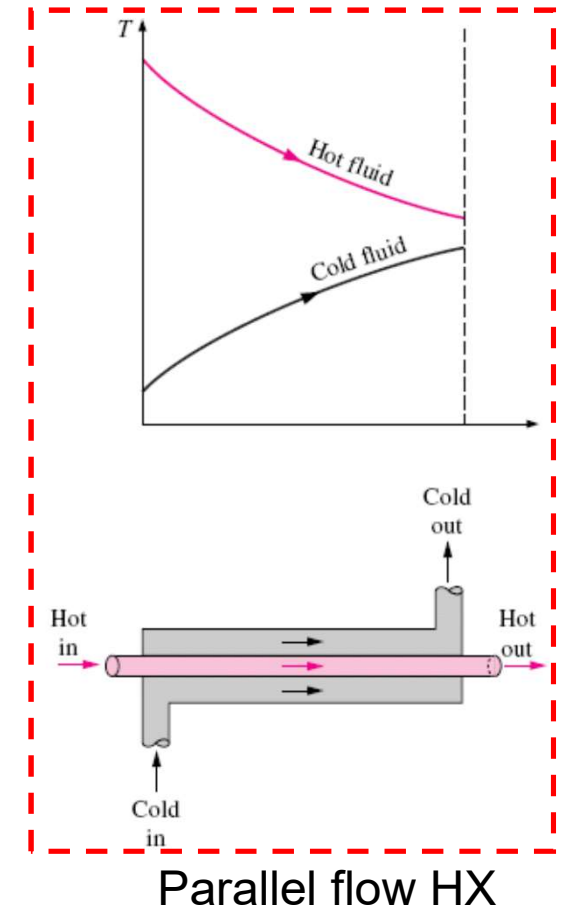
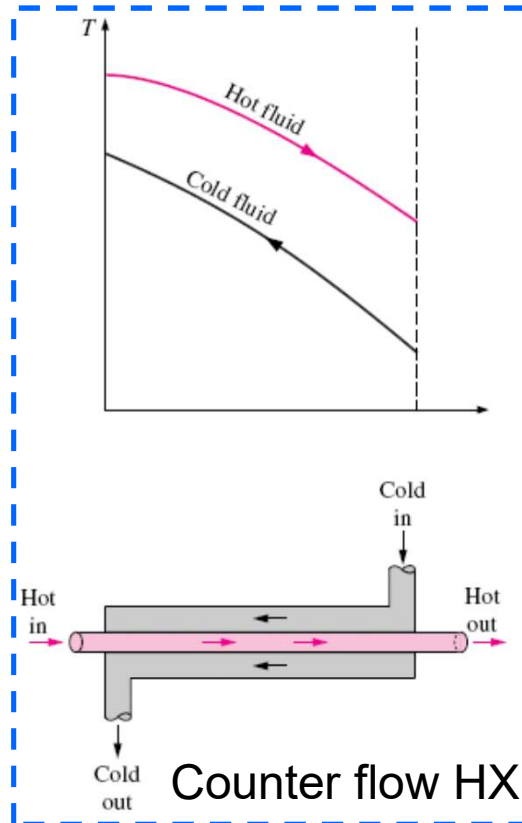
Different heat transfer applications require different types of hardware and different configurations of heat transfer equipment.



MECE 371: 5.1 HX Fundamentals

□ Classification: Double pipe HX

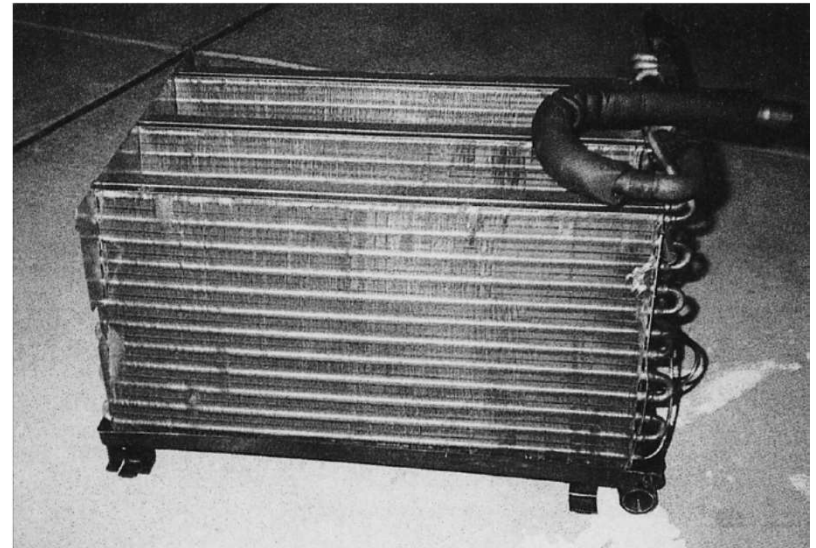
- The simplest type of heat exchanger
- One fluid flows through the smaller pipe while the other fluid flows through the annulus.
- Two flow arrangements:
 - parallel flow
 - counter flow



MECE 371: 5.1 HX Fundamentals

□ Classification: Compact HX

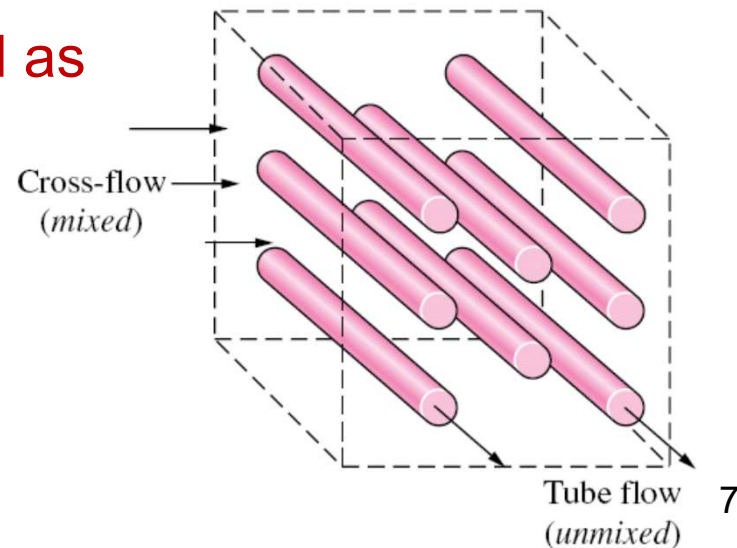
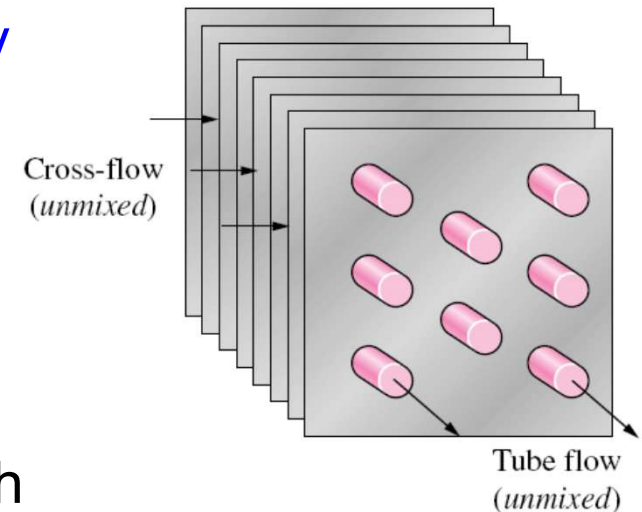
- Large heat transfer surface area per unit volume.
- Area density, β — heat transfer surface of a heat exchanger to volume ratio.
- For Compact HX, $\beta > 700 \text{ m}^2/\text{m}^3$.
- Examples:
 - car radiators ($\beta \approx 1000 \text{ m}^2/\text{m}^3$),
 - glass-ceramic gas turbine HX ($\beta \approx 6000 \text{ m}^2/\text{m}^3$),
 - the human lung ($\beta \approx 20,000 \text{ m}^2/\text{m}^3$).



MECE 371: 5.1 HX Fundamentals

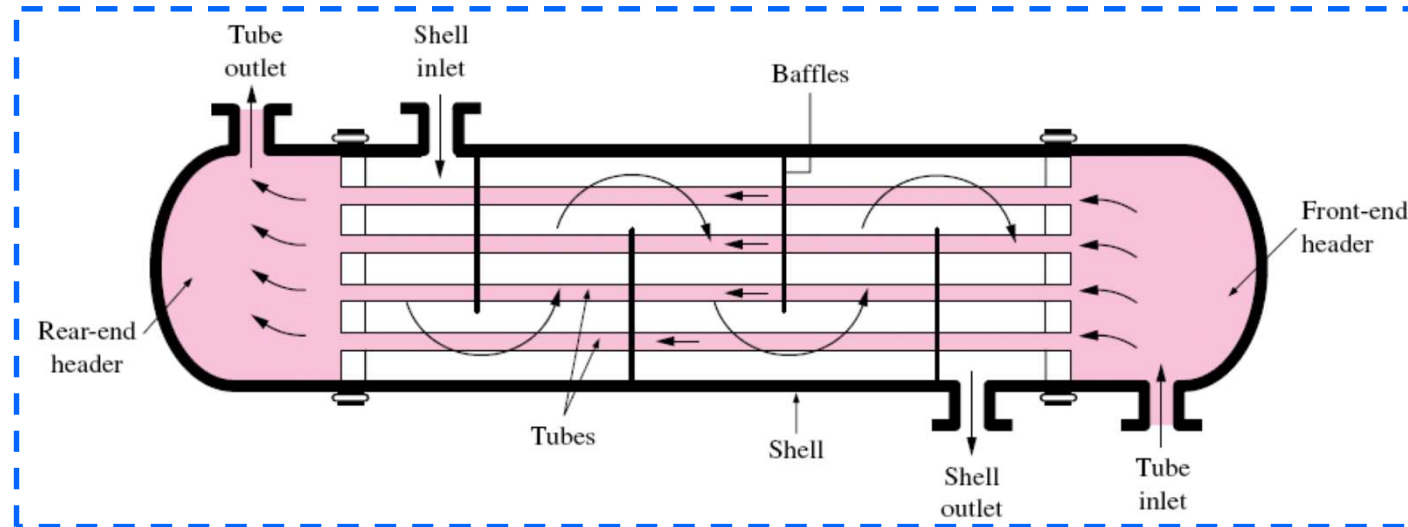
□ Classification: Compact HX

- Compact heat exchangers are commonly used in
 - gas-to-gas
 - gas-to-liquid
 - liquid-to-gas
- Typically cross-flow configuration where the two fluids move perpendicular to each other.
- The cross-flow is further classified as
 - unmixed flow
 - mixed flow



MECE 371: 5.1 HX Fundamentals

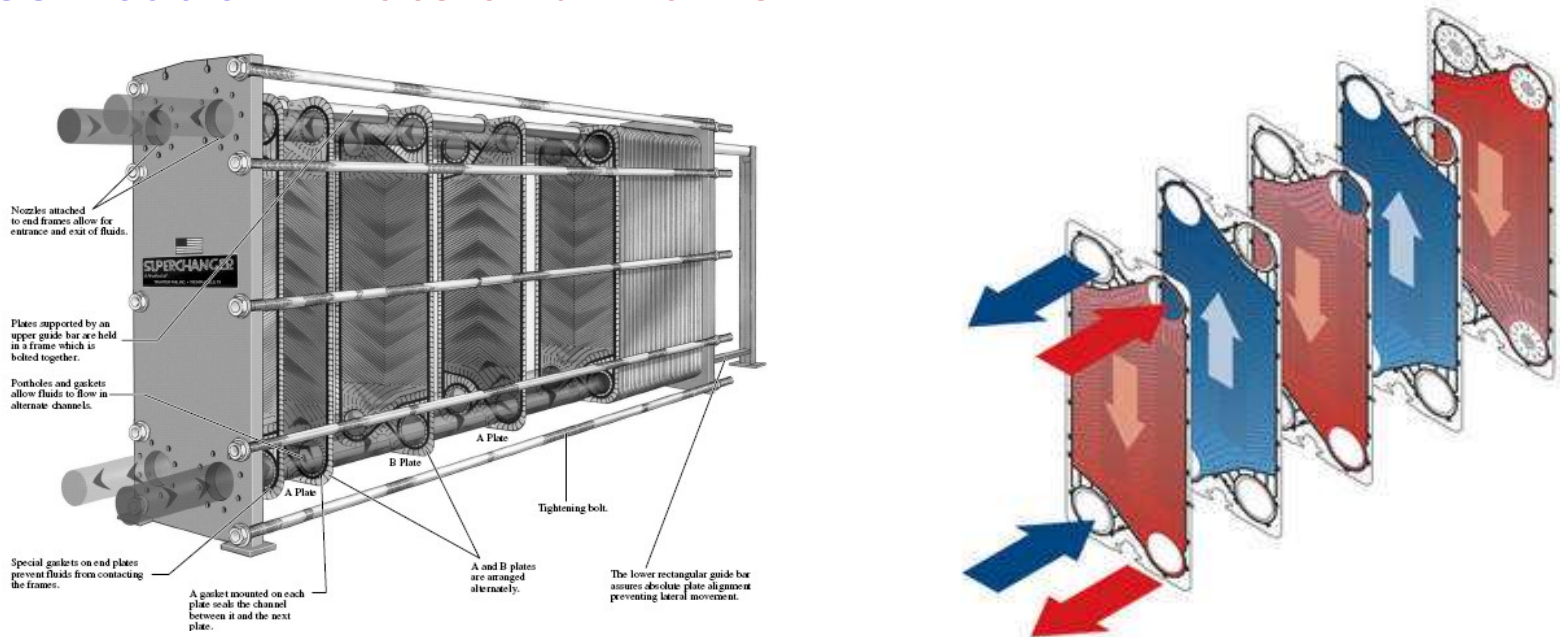
□ Classification: Shell-and-Tube HX



- The most common type of heat exchanger in industrial applications.
- Large number of tubes are packed in a shell with their axes parallel to that of the shell.
- The other fluid flows outside the tubes through the shell.
- *Baffles* are commonly placed in the shell.
- These are relatively large in size and weight.

MECE 371: 5.1 HX Fundamentals

□ Classification: Plate-and-Frame HX



- Consists of a series of plates with corrugated flat flow passages.
- The hot and cold fluids flow in alternate passages
- Well suited for liquid-to-liquid heat exchange applications, provided that the hot and cold fluid streams are at about the same pressure.

4.5 Heat Exchanger (HX)

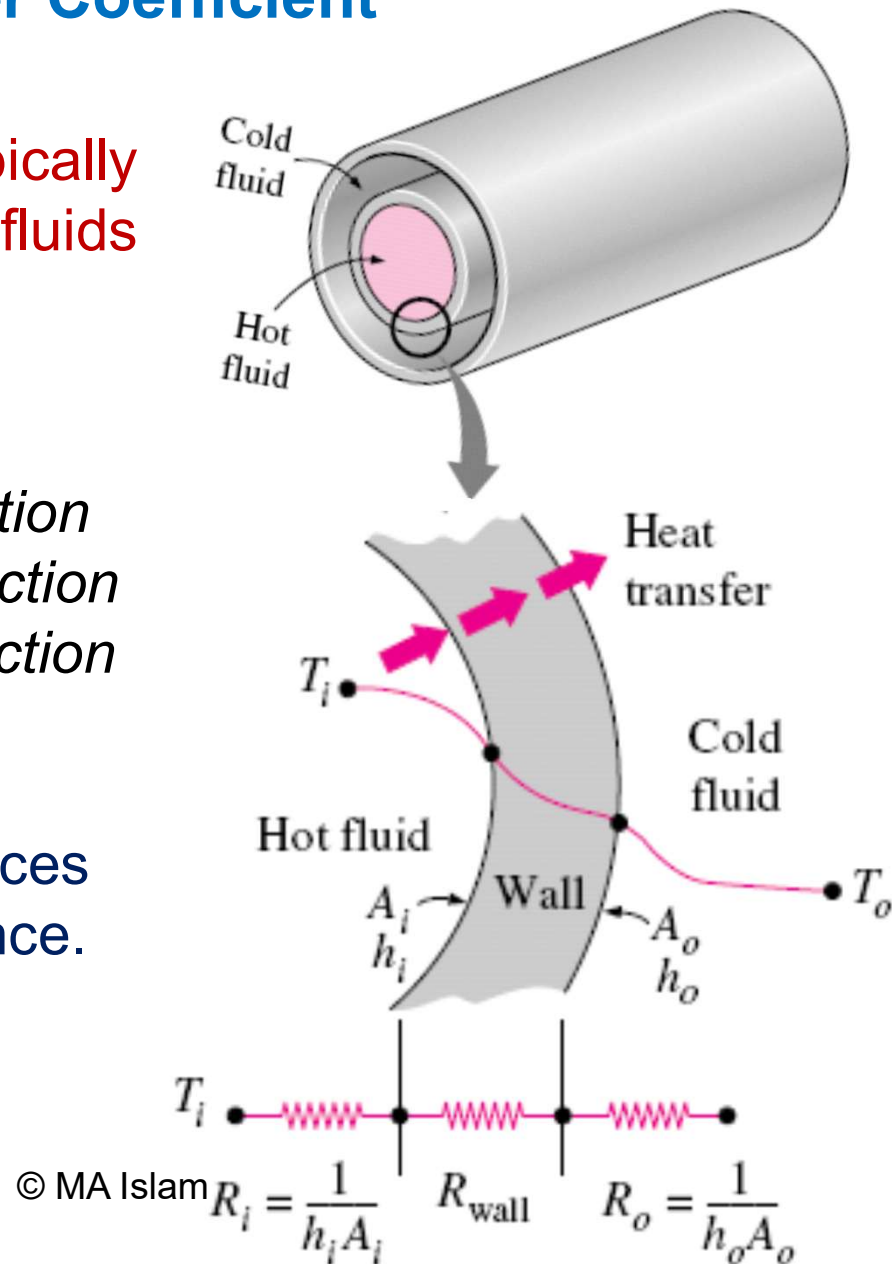
□ Classification:

- Double pipe HX
- Compact HX
- Shell-and-tube HX
- Plate-and-Frame HX

4.5 Heat Exchanger (HX)

□ The Overall Heat Transfer Coefficient

- A heat exchanger typically involves two flowing fluids separated by a solid wall.
- Heat is transferred
 - hot fluid to wall: *convection*
 - through the wall: *conduction*
 - wall to cold fluid: *convection*
- The thermal resistances:
 - two convection resistances
 - one conduction resistance.

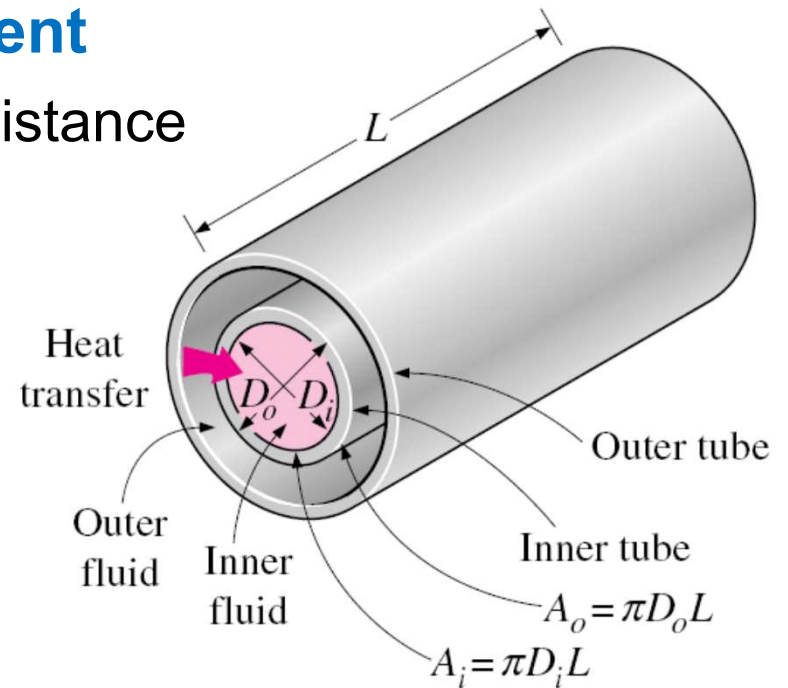


4.5 Heat Exchanger (HX)

□ The Overall Heat Transfer Coefficient

- For a double-pipe HX, the thermal resistance of the tube wall is:

$$R_{wall} = \frac{\ln(D_o/D_i)}{2\pi kL}$$



- The total thermal resistance

$$R_{total} = R_i + R_{wall} + R_o = \frac{1}{h_i A_i} + \frac{\ln(D_o/D_i)}{2\pi kL} + \frac{1}{h_o A_o} \dots\dots(5.1)$$

$$\dot{Q} = \frac{\Delta T}{R} = UA\Delta T = U_i A_i \Delta T = U_o A_o \Delta T \dots\dots(5.2)$$

4.5 Heat Exchanger (HX)

□ The Overall Heat Transfer Coefficient

- When the wall thickness of the tube is small and the thermal conductivity of the tube material is high,

$$R_{\text{wall}}=0 \text{ and } A_i \approx A_o \approx A_s$$

- Eq.(5.2) simplifies to

$$\frac{1}{U} \approx \frac{1}{h_i} + \frac{1}{h_o} \quad \dots\dots(5.3)$$

- When $h_i \gg h_o$

$$\frac{1}{U} \approx \frac{1}{h_o}$$

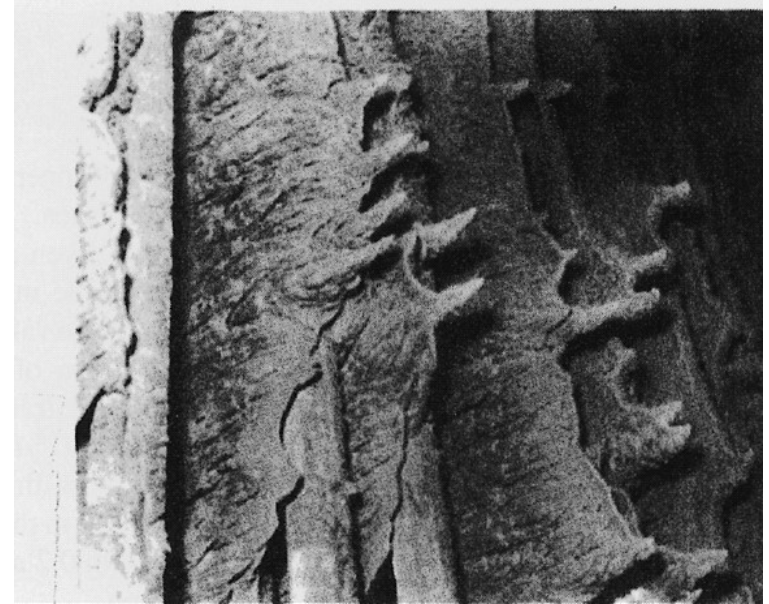
- When $h_i \ll h_o$

$$\frac{1}{U} \approx \frac{1}{h_i}$$

4.5 Heat Exchanger (HX)

□ Fouling Factor

- The performance of HXs usually deteriorates with time as a result of accumulation of deposits on heat transfer surfaces.
- The layer of deposits imposes additional resistance to heat transfer and causes the rate of heat transfer in a HX to decrease.



- The **fouling factor** R_f — The net effect of these accumulations on heat transfer.
- Common types of fouling:
 - precipitation of solid deposits in a fluid on the heat transfer surfaces.
 - corrosion and other chemical fouling
 - Biofouling

4.5 Heat Exchanger (HX)

□ Next Class

Heat Exchanger Analysis