Heat Exchangers

Learning Objectives

- Understand basic principles of the design and operation of heat exchangers
- Be able to list and discuss various applications of heat exchangers
- Be able to describe applications of various types of heat exchangers
HEAT EXCHANGERS

• Heating and cooling systems
  o use a flowing fluid to provide the heating or cooling effect

  o Examples:  > refrigeration systems
               > steam jacketed kettles
               > plate heat exchangers

• Need to know how much heat can be transferred to (or from) a fluid flowing in a system

• Other important factors include:
  o fluid flow rate
  o fluid properties
  o fluid thickness (or pipe diameter)

HEAT EXCHANGERS

• Heat exchangers are used extensively in many food operations

• Used where many heating and cooling operations are involved

• Basis function is to transfer heat from one fluid to another

• Some cases fluids are mixed - when steam is added to water

• In most cases, the fluids must be physically separated by a plate, pipe wall, or other good conductor
HEAT EXCHANGERS

- Simple heat exchanger - one pipe mounted inside another

- Double-type heat exchanger is excellent for analyzing heat exchanger characteristics

HEAT EXCHANGERS: Multi Tube Tubular HX

Fig. 6.1.19 End of a multtube tubular heat exchanger.

1 Product tubes surrounded by cooling medium
2 Double O-ring seal
HEAT EXCHANGERS

Shell-and-tube heat exchanger
- has tubes mounted inside an outer shell
- One fluid flows through the tube while the other is in the shell surrounding the tubes

HEAT EXCHANGERS

Shell-and-tube HX
- bundle of parallel tubes contained within a shell
- tube-side: food product
- shell-side: heating or cooling medium
- shell side not sanitary
- **NO** regeneration
- very inexpensive
Example: Tube HX

Plate heat exchanger.

Flow Pattern in Series of Plates
HEAT EXCHANGERS

Swept-surface HX

- viscous fluids
  - cheese sauce
  - pudding
- NO regeneration
- expensive

Fig. 6.1.20 Vertical type of scraped-surface heat exchanger.

1. Cylinder
2. Rotor
3. Blade

Vertical type of scraped-surface heat exchanger
HEAT EXCHANGERS

- Heat exchangers also identified by the flow pattern of the fluids in the exchanger
- Double-pipe heat exchanger - a parallel flow unit since the fluids flow in parallel.

Reversing either fluid would produce a counter flow system.
HEAT EXCHANGERS

• Heat exchangers vary greatly in the design to obtain desired heat transfer characteristics
• Cross-flow system - fluids flow perpendicular to each other
• Combinations of several designs are sometimes used in special situations

SPIRAL-TUBE HX
• helical tube within shell
• used on some aseptic systems

STEAM-INFUSION HX
• thin layer of food cascades through steam chamber
• direct contact with steam=dilution
• viscous foods
• possibly foods with particulates
The concentric tubes in a triple tube heat exchanger

Consentic tubes wound cylindrically to form coils.
The unit is placed in a stainless steel jacket

HEAT EXCHANGERS : Analysis

- Assume the following:
  - double-pipe heat exchanger
    - hot fluid flowing in the inner pipe
    - cooler fluid flows in outer pipe
    - flow is parallel
**HEAT EXCHANGERS : Analysis**

Temperature distribution along length of heat exchanger

ASSUMPTIONS
-- Steady state flow
-- No heat conduction parallel to direction of fluid flow
-- Overall heat transfer "U" is constant throughout the length

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**HEAT EXCHANGERS : Analysis**

**Temperature distribution along length of heat exchanger**

\[ \frac{dT}{dq} = \frac{\Delta T_2 - \Delta T_1}{q} \]

\[ dq = U\Delta TdA_i \]

\[ \frac{dT}{U\Delta TdA_i} = \frac{\Delta T_2 - \Delta T_1}{q} \]

\[ \frac{1}{U_i} \int \left( \frac{dT}{dT} \right) = \frac{\Delta T_2 - \Delta T_1}{q} \int dA_i \]

\[ q = U_i \Delta A_i \frac{\Delta T_2 - \Delta T_1}{\ln \frac{\Delta T_2}{\Delta T_1}} \]

**Energy balance:**

**Total energy lost (by hot fluid):**

\[ q_h = m_1 c_p (T_{hI} - T_{hII}) \]

**Total energy lost (by cold fluid):**

\[ q_c = m_1 c_p (T_{cI} - T_{cII}) \]

Where:

- \( m_1 \) = mass flow rate of hot fluid (kg/s)
- \( c_p \) = specific heat of hot fluid (kJ/kg °C)
- \( T_{hI} \) = temperature of hot fluid at position I (°C)
- \( T_{hII} \) = temperature of hot fluid at position II (°C)
- \( q_h \) = rate of heat transferred from hot to cold fluid (kJ/s or kW)

**ASSUMPTIONS**

- Steady state flow
- No heat conduction parallel to direction of fluid flow
- Overall heat transfer \( U \) is constant throughout the length
Contoh Soal

Diketahui :
- Laju aliran air pendingin = 0.028 kg/s
- Luas area HX = 0.1226 m²
- Kapasitas panas air = 4.1868 kJ/kg.°K

Ditanya :
- Berapa nilai U (overall Heat Transfer Coef)?
Contoh Soal

Dari data yang ada:
→ \( q = m \cdot c_p \cdot \Delta T; \)
Diketahui: \( m_c = 0.028 \text{ kg/s} \)
\( c_p = 4.1868 \text{ kJ/kg.°C} \)

Jadi,
→ \( q = (0.028 \text{ kg/s})(4.1868 \text{ kJ/kg.°C})(51.8-28.1)\text{°C} \)
\( = 2.778 \text{ kW} \)

Menggunakan data yang ada (lihat grafik), cari LMTD

\[ \text{LMTD} = \frac{[(56.8 - 51.8) - (67.7 - 28.1)]}{\ln \left( \frac{56.8 - 51.8}{67.7 - 28.1} \right)} \]
\( = 16.72 \text{ °C} \)

Diketahui \( A = 0.1226 \text{ m}^2 \)

Maka, sesuai dengan teori Pindah panas
→ \( q = U \cdot A \cdot \Delta T_{m} = U \cdot A \cdot \text{(LMTD)} \)
\( U = q / (A \cdot \text{LMTD}) \)
\( U = (2.778 \text{ kW}) / (0.1226 \ast 16.72) \text{m}^2\cdot°\text{C} = 1.355 \text{ kW/m}^2\cdot°\text{C} \)
HEAT EXCHANGERS

Plate HX

- regenerative heat/cool
- compact
- THE standard for milk pasteurization
- low-viscosity fluids
  - juice
  - UHT milk