Topic - Fouling Factors

Fouling

The deposition of any undesired material on heat transfer surfaces is called fouling. Fouling may significantly impact the thermal and mechanical performance of heat exchangers. Fouling is a dynamic phenomenon which changes with time.

Fouling increases the overall thermal resistance and lowers the overall heat transfer coefficient of heat exchangers. Fouling also impedes fluid flow, accelerates corrosion and increases pressure drop across heat exchangers.

Different types of fouling mechanisms have been identified. They can occur individually but often occur simultaneously. Descriptions of the most common fouling mechanisms are provided below:

<u>Scaling/Crystallization Fouling:</u>

Scaling is the most common type of fouling and is commonly associated with inverse solubility salts such as calcium carbonate ($CaCO_3$) found in water. Reverse solubility salts become less solute as the temperature increases and thus deposit on the heat exchanger surface. Scale is difficult to remove mechanically and chemical cleaning may be required.

Fouling Factors in Heat Exchangers .are The fouling factor represents the theoretical resistance to heat flow due to a build-up of a layer of dirt or other fouling substance on the tube surfaces of the heat exchanger, but they are often overstated by the end user in an attempt to minimise the frequency of cleaning.

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Problem 12.19: *A feed water heater uses steam condensing at 120°C to heat water from 30°C to 90°C in a shell and tube heat exchanger at a rate of 5 kg/s. The overall heat transfer coefficient is equal to 2000 W/m^2K. Due to usage deposits have formed on the surfaces resulting in a fouling resistance of 0.0009 Km^2/W. Determine the water exit temperature if flow rates and inlet temperatures are maintained.*

Solution: As it is a condenser, it can be treated as counter flow exchanger. As performance under a different operating condition is to be studied NTU method is used.

$$\varepsilon = \frac{90-30}{120-30} = \frac{60}{90} = 0.667 = 1 - e^{-NTU}$$

Solving **NTU = 1.0986**

$$NTU = UA/C_{min} \quad \therefore \quad A = 11.48\ m^2$$

Due to fouling, the value of U is changed. C_{min} and area remain unaltered.

$$\frac{1}{U_d} - \frac{1}{U_c} = \text{fouling factor}$$

U_d–overall heat transfer coefficient for dirty surface

U_c–overall heat transfer coefficient for clean surface

$$\frac{1}{U_d} = \frac{1}{2000} + 0.0009 \quad \therefore \quad U_d = 714.29\ W/m^2K$$

$$NTU = UA/C_{min} = 714.29 \times 11.48/5 \times 4180 = 0.3923$$

$$\therefore \quad \varepsilon = 0.325 = \frac{T_{c2}-T_{c1}}{T_{h1}-T_{c1}} = \frac{T_{c2}-30}{120-30}$$

$$\therefore \quad T_{c2} = 59.2°C$$

Water outlet temperature is reduced from 90 to 59.2°C

Heat flow = 5 × 4.180 (59.2 – 30) = **610.44 kW**

as compared to 1254 kW. A reduction more than 50%. This problem can be inverted to determine the fouling factor. This is the reason for use of fouling factor in design.

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Problem 12.20: *A feed water heater having 5.74 m² area was used to heat water from 30°C at a rate of 2.5 kg/s, using steam condensing at 120°C. The exit temperature was measured as 90°C. Determine the value of overall heat transfer coefficient. After 3 years of operation, for the same flow rates and inlet conditions, the outlet temperature measured only 80°C. Determine the value of fouling resistance.*

Solution: This problem can preferably be solved by NTU method.

As it is a condensing unit $C_c = C_{min}$

$$\varepsilon = \frac{90 - 30}{120 - 30} = \frac{60}{90}$$

$$\therefore \quad NTU = -\ln(1 - \varepsilon) = 1.0986$$

$$NTU = UA/C_{min} = U \times 5.74/(2.5 \times 4180)$$

$$\therefore \quad \mathbf{U = U_c = 2000.09\ W/m^2 K}$$

After service the fluid is heated only to 80°C and so,

$$\varepsilon = \frac{80 - 30}{120 - 30} = \frac{50}{90} \quad \therefore \quad NTU = 0.8109$$

$$\therefore \quad \mathbf{U_d = 1476.35\ W/m^2 K}$$

Fouling resistance $= \frac{1}{U_d} - \frac{1}{U_c} = \mathbf{0.000177\ Km^2/W}$

References:

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3. MIT open courseware – https://ocw.mit.edu/courses/mechanical-engineering

Other web sources