GPHE heat transfer theory and calculations

Plate heat exchanger calculation method

To solve a thermal problem, we need to know several parameters. Further data can then be determined.

The six most important parameters include:

- The amount of heat to be transferred (heat load)
- The inlet and outlet temperatures on the primary and secondary sides
- The maximum allowable pressure drop on the primary and secondary sides
- The maximum operating temperature
- The maximum operating pressure
- The flowrate on the primary and secondary sides

If the flow rate, specific heat and temperature difference on one side are known, the heat load can be calculated.

Calculation method

The heat load of a heat eschanger can be derived from the following two formulae:

1. Heat load, Theta and LMTD calculation

$$P = m \cdot c_p \cdot \delta t \ (m = \frac{P}{c_p \cdot \delta t}\ ;\ \delta t = \frac{P}{m \cdot c_p})$$

$$P = k \cdot A \cdot LMTD$$

Where:

P = heat load (btu/h)
m = mass flow rate (lb/h)
c_p = specific heat (btu/lb °F)
δt = temperature difference between inlet and outlet on one side (°F)
k = heat transfer coefficient (btu/ft^2 h °F)
A = heat transfer area (ft^2)
LMTD = log mean temperature difference

$$\Theta = \text{Theta-value} = \frac{\delta t}{LMTD} = \frac{k \cdot A}{m \cdot c_p}$$

T1 = Temperature inlet – hot side
T2 = Temperature outlet – hot side
T3 = Temperature inlet – cold side
T4 = Temperature outlet – cold side

LMTD can be calculated by using the following formula, where $\Delta T1 = T1–T4$ and $\Delta T2 = T2–T3$

$$LMTD = \frac{\Delta T1 - \Delta T2}{\ln \frac{\Delta T1}{\Delta T2}}$$

2. Heat transfer coefficient and design margin

The total overall heat transfer coefficient k is defined as:

Where: $$\frac{1}{k} = \frac{1}{\alpha_1} + \frac{1}{\alpha_2} + \frac{\delta}{\lambda} + R_f = \frac{1}{k_c} + R_f$$

The design margin (M) is calculated as: $M = \frac{k_c - k}{k}$

α_1 = The heat transfer coefficient between the warm medium and the heat transfer surface (btu/ft^2 h °F)
α_2 = The heat transfer coefficient between the heat transfer surface and the cold medium (btu/ft^2 h °F)
δ = The thickness of the heat transfer surface (ft)
R_f = The fouling factor (ft^2 h °F/btu)
λ = The thermal conductivity of the material separating the medias (btu/ft^2 h °F)
k_c = Clean heat transfer coefficient (R_f=0) (btu/ft^2 h °F)
k = Design heat transfer coefficient (btu/ft^2 h °F)
M = Design Margin (%)

Combination of these two formulas gives: $M = k_c \cdot R_f$

i.e the higher k_c value, the lower R_f-value to achieve the same design margin.

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