Design and control of different pressure thermally coupled reactive distillation for methyl acetate hydrolysis

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SUPPORTING INFORMATION

1. The equipment is sized as follows:

(1) The heat transfer area (A) in the condenser and reboiler

$$A[m^2] = \frac{Q}{U \cdot \Delta T}$$

Here, ΔT (K) is the logarithmic mean temperature difference; Q (kW) is the heat duty; U (kW/(K·m^2)) is the heat transfer coefficient.

(2) The height of the column

$$L_c[m] = (N_{actual} - 1) \times 0.6096 + 6$$

Here, 0.6096 m is the tray spacing and 6 m is the disengagement.

2. The capital cost is calculated as follows:

(1) Installed column cost

$$\text{Installed column shells cost[\$]} = \frac{M\ \&\ S}{280} \times 937.636 \times D^{1.066} \times L_c^{0.802} \times (2.18 + F_c)$$

Here, $F_c = F_m \times F_p$; F_m and F_p are the construction material and pressure range, respectively. The ratio of Marshall & Swift index ($M\ \&\ S$) is specified at 1468.2. F_m is set at 1 and F_p is set at 1.

$$\text{Installed column trays cost[\$]} = \frac{M\ \&\ S}{280} \times 97.243 \times D^{1.55} \times h_T \times F_c$$

Here, $F_c = F_s + F_t + F_m$, and $h_T(\text{m}) = (N_{actual} - 1) \times 0.6096$.

(2) Installed heat exchanger cost

$$\text{Installed heat exchanger cost[\$]} = \frac{M\ \&\ S}{280} \times 474.668 \times A^{0.65} \times (2.29 + F_c)$$

Here, $F_c = (F_d + F_p) \times F_m$. For reboiler, $F_c = (1.35 + 0) \times 1 = 1.35$.

(3) Installed compressor cost

$$\text{Installed compressor cost[\$]} = \frac{M\ \&\ S}{280} \times 666.1 \times P^{0.82} F_c$$

Here, F_c varies with design types as follows: 1.00 for centrifugal (motor), 1.07 for reciprocating (steam), 1.15 for centrifugal (turbine), and 1.29 and 1.82 for reciprocating (motor and gas engine).

3. The operating cost is calculated as follows:

(1) Steam cost

$$\text{Steam cost[\$/y]} = C_s \times \frac{Q_R}{\lambda_V} \times 8000 \times 3600$$

Here, C_s (\$/kg) is the saturated steam price; λ_V (kJ/kg) is the latent heat of the steam which depends on the bottom temperature; Q_R (kW) is the reboiler heat duty.

(2) Cooling water cost

$$\text{Cooling water cost[\$/y]} = \frac{0.03}{3.785} \times \frac{Q_C}{\Delta T \cdot C_p \cdot 1000} \times 8000 \times 3600$$

Here, Q_C (kW) is the condensor heat duty; C_p (kJ/(kg·K)) is the specific heat capacity of the cooling water; ΔT (K) is the temperature difference between the outlet and inlet of the cooling water.

(3) Catalyst cost (assuming a catalyst life of 3 months)

$$\text{Catalyst cost[\$]} = \text{catalyst loading[kg]} \times 7.7162 \frac{\$}{\text{kg}}$$