Thermal Processes

Aim of the work

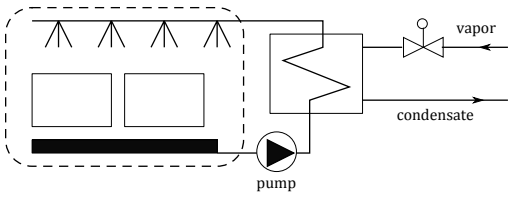
Differential equations from first principle law. Energy conservation law.

Report

- Do not provide screenshots of the workspace in MATLAB, and black Scope graphs, use Figures instead!
- Explain ODE parameters, analyze the results using time domain representations.

1 Autoclave for food sterilization

Autoclave for food sterilization under pressure consists of 0.8 t potato and 0.2 t water. Autoclave construction weight is 1.0 t. The autoclave is heated by the steam of temperature $T = 110$ °C which consumption is adjustable (signal 0–100%) between $0 \dots 1500$ kg/h.



- Specific heat capacities: of water $c_{w.p} = 4.18$ kJ/(kg·°C) and iron $c_i = 0.44$ kJ/(kg·°C),
- Water heat of evaporation (specific energy) is $e = 2256$ kJ/kg,
- Potato and water features are similar.

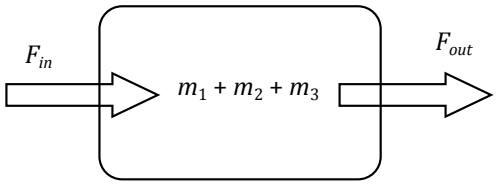
With 5% of steam consumption autoclave reaches the temperature of 90 °C (if temperature of the environment is +20 °C).

Work flow

1. Provide the equation describing thermal process.
2. What is the transfer function of the autoclave?
3. Could be the temperature rise greater than 7.0 °C/min?
4. If steam inflow is closed at 95 °C
   - How fast does temperature decrease?
   - What is the temperature of autoclave in 1.5 h?

Comments

- iron + water + potato



Q–quantity of heat,

$F = \mathrm{d}Q/\mathrm{d}t$—heat flow,

T–autoclave temperature,

T_e–environmental temperature,

$\mathrm{d}U = \mathrm{d}t = F_{\mathrm{in}} - F_{\mathrm{out}}$—thermal process in autoclave.

1. Autoclave consists of 3 materials (iron, water, potato) with a temperature T:
   - Quantity of the heat in the autoclave is
   $$Q = Q_1 + Q_2 + Q_3 = (c_1 m_1 + c_2 m_2 + c_3 m_3)T = \sum c_i m_i \cdot T$$
   - Process equation
   $$\frac{\mathrm{d}(\sum c_i m_i \cdot T)}{\mathrm{d}t} = F_{\mathrm{in}} - F_{\mathrm{out}},$$
   where $F_{\mathrm{in}} = Q_s$—quantity of heat given by steam,
   $F_{\mathrm{out}} = UA(T - T_e) = K_l(T - T_e)$—cooling into environment.
   - Steam temperature is 110 °C, autoclave temperature rate is $20 \ldots 90$ °C
2. Steam inflow quantity of heat Q_s does not depend on the temperature T of the autoclave.
   Why is that?
   - Cooling process depends on the temperature T : $-K_l(T - T_e)$.
   - During steam condensation all obtained heat is transferred into circulating water condensate.
   Assume that circulation flow is 10 l/s, how fast does the temperature ΔT change with the maximum steam consumption?
   $$F_{\mathrm{in}} = Q_{\max} = eq_s = c_w q_w \Delta T,$$
   where $Q = \mathrm{const}$ until $T < T_{\mathrm{steam}}$.
3. Steady-state $Q = K_l(T - T_e)$ → coefficient $K_l = \ldots$ kW/K.
4. Cooling $F_{\mathrm{in}} = 0$ → $\sum c_i m_i \mathrm{d}T/\mathrm{d}t = -K_l(T_0 - T_e)$.