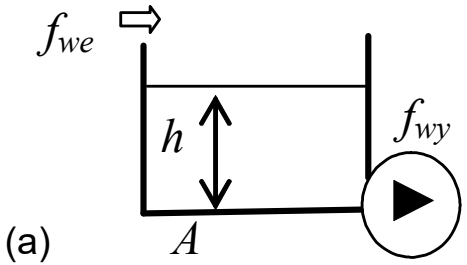
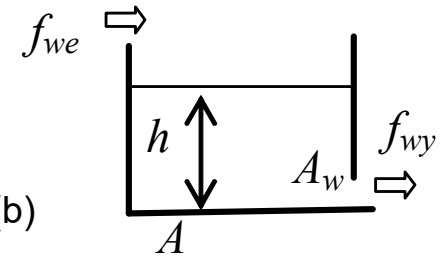
Otwarte układy hydrauliczne – zasada konstrukcji modelu



(a)



(b)

1) Zawartość magazynu $V(t) = Ah(t)$ $\left[m^2 \cdot m = m^3\right]$

2) Zmiana zawartości magazynu $\dfrac{dV(t)}{dt} = A\dfrac{dh(t)}{dt} = A\dot{h}(t)$ $\left[m^2 \cdot \dfrac{m}{s} = \dfrac{m^3}{s}\right]$

3) Bilans strumieni wpływających i wypływających [m3/s] $A\dot{h}(t) = f_{we}(t) - f_{wy}(t)$

(a) $f_{wy}(t)$

(a) $A\dot{h}(t) = f_{we}(t) - f_{wy}(t)$

(b) $f_{wy}(t) = A_w\sqrt{2gh(t)} \approx ah(t)$

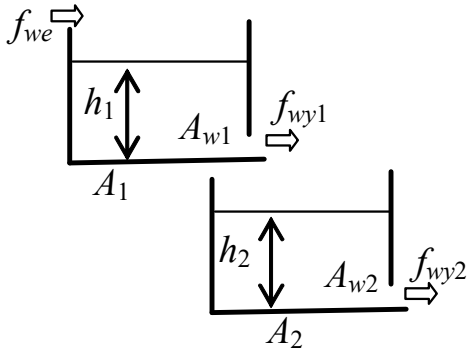
(b_1) $A\dot{h}(t) = f_{we}(t) - A_w\sqrt{2gh(t)}$

(b_2) $A\dot{h}(t) = f_{we}(t) - ah(t)$

4) Zmienne wejściowe i wyjściowe, kompletność modelu

5) Identyfikacja wartości parametrów

Otwarte układy hydrauliczne



$$\begin{cases} A_1\dot{h}_1(t) = f_{we}(t) - f_{wy1}(t) \\ A_2\dot{h}_2(t) = f_{wy1}(t) - f_{wy2}(t) \end{cases}$$

$$f_{wy1}(t) = A_{w1}\sqrt{2gh_1(t)} \approx a_1 h_1(t)$$

$$f_{wy2}(t) = A_{w2}\sqrt{2gh_2(t)} \approx a_2 h_2(t)$$

$$\begin{cases} A_1\dot{h}_1(t) = f_{we}(t) - A_{w1}\sqrt{2gh_1(t)} \\ A_2\dot{h}_2(t) = A_{w1}\sqrt{2gh_1(t)} - A_{w2}\sqrt{2gh_2(t)} \end{cases}$$

$$\begin{cases} A_1\dot{h}_1(t) = f_{we}(t) - a_1 h_1(t) \\ A_2\dot{h}_2(t) = a_1 h_1(t) - a_2 h_2(t) \end{cases}$$

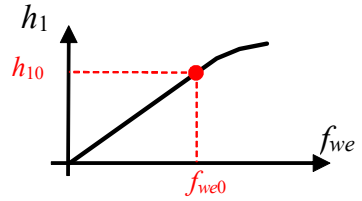
Równania dynamiki

$$\begin{cases} 0 = f_{we} - A_{w1}\sqrt{2gh_1} \\ 0 = A_{w1}\sqrt{2gh_1} - A_{w2}\sqrt{2gh_2} \end{cases} \Rightarrow \quad h_1 = \frac{f_{we}^2}{2gA_{w1}^2} \qquad h_2 = \frac{f_{we}^2}{2gA_{w2}^2}$$

$$\begin{cases} 0 = f_{we} - a_1 h_1 \\ 0 = a_1 h_1 - a_2 h_2 \end{cases} \Rightarrow \quad h_1 = \frac{f_{we}}{a_1} \qquad h_2 = \frac{f_{we}}{a_2}$$

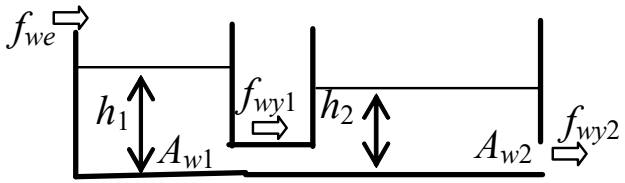
Równania statyczne

Charakterystyki statyczne
Punkt równowagi
Punkt pracy



Identyfikacja parametrów (A_1, A_2, A_{w1} , A_{w2})

Otwarte układy hydrauliczne



$$\begin{cases} A_1\dot{h}_1(t) = f_{we}(t) - f_{wy1}(t) \\ A_2\dot{h}_2(t) = f_{wy1}(t) - f_{wy2}(t) \end{cases}$$

$$f_{wy1}(t) = A_{w1}\sqrt{2g\left(h_1(t) - h_2(t)\right)} \approx a_1\left(h_1(t) - h_2(t)\right)$$

$$f_{wy2}(t) = A_{w2}\sqrt{2gh_2(t)} \approx a_2 h_2(t)$$

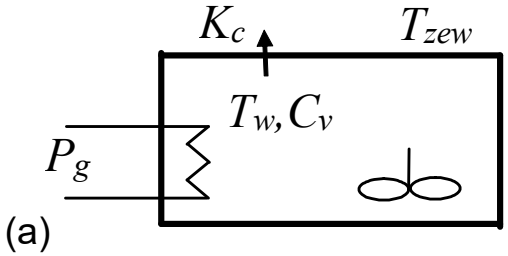
$$\begin{cases} A_1\dot{h}_1(t) = f_{we}(t) - A_{w1}\sqrt{2g\left(h_1(t) - h_2(t)\right)} \\ A_2\dot{h}_2(t) = A_{w1}\sqrt{2g\left(h_1(t) - h_2(t)\right)} - A_{w2}\sqrt{2gh_2(t)} \end{cases}$$

$$\begin{cases} 0 = f_{we} - A_{w1}\sqrt{2g\left(h_1 - h_2\right)} \\ 0 = A_{w1}\sqrt{2g\left(h_1 - h_2\right)} - A_{w2}\sqrt{2gh_2} \end{cases} \Rightarrow h_1 = \ldots \quad h_2 = \ldots$$

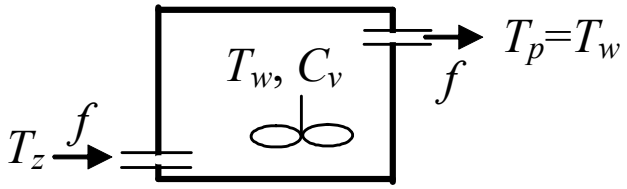
$$\begin{cases} A_1\dot{h}_1(t) = f_{we}(t) - a_1\left(h_1(t) - h_2(t)\right) \\ A_2\dot{h}_2(t) = a_1\left(h_1(t) - h_2(t)\right) - a_2 h_2(t) \end{cases}$$

$$\begin{cases} 0 = f_{we} - a_1\left(h_1 - h_2\right) \\ 0 = a_1\left(h_1 - h_2\right) - a_2 h_2 \end{cases} \Rightarrow h_1 = \ldots \quad h_2 = \ldots$$

Obiekty cieplne – zasada konstrukcji modelu



(a)



(b)

Założenie o doskonałym mieszaniu

1) Zawartość magazynu $$Q(t) = c_p \rho V T(t) = C_V T(t)$$ $$\left[\frac{J}{kgK}\frac{kg}{m^3}m^3K = \frac{J}{K}\cdot K = J\right]$$

2) Zmiana zawartości magazynu $$\frac{dQ(t)}{dt} = C_V \frac{dT_w(t)}{dt} = C_V \dot{T}_w(t)$$ $$\left[\frac{J}{K}\cdot\frac{K}{s} = \frac{J}{s} = \frac{Ws}{s} = W\right]$$

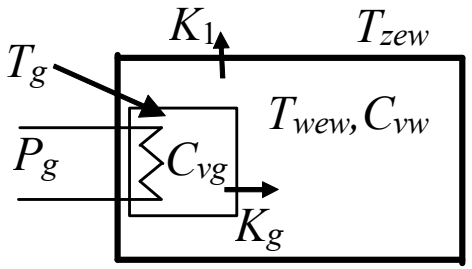
3) Bilans strumieni wpływających i wypływających [W] $$C_v \dot{T}_w(t) = P_{we}(t) - P_{wy}(t)$$

$$C_v \dot{T}_w(t) = P_g(t) - K_c\left(T_w(t) - T_{zew}(t)\right)$$

$$C_v \dot{T}_w(t) = c_p \rho\, f(t) T_z(t) - c_p \rho\, f(t) T_w(t)$$

4) Zmienne wejściowe i wyjściowe, kompletność modelu

5) Identyfikacja wartości parametrów



$$\begin{cases} C_{vg}\dot{T}_g(t) = P_g(t) - K_g\left(T_g(t) - T_{wew}(t)\right) \\ C_{vw}\dot{T}_{wew}(t) = K_g\left(T_g(t) - T_{wew}(t)\right) - K_1\left(T_{wew}(t) - T_{zew}(t)\right) \end{cases}$$

wy: T_g, T_{wew}

$T_g(t)$, $T_{wew}(t)$

we: P_g, T_{zew}

$P_g(t)$, $T_{zew}(t)$

Równania statyczne

$$\begin{cases} 0 = P_g - K_g\left(T_g - T_{wew}\right) \\ 0 = K_g\left(T_g - T_{wew}\right) - K_1\left(T_{wew} - T_{zew}\right) \end{cases}$$

$$P_g = K_g\left(T_g - T_{wew}\right) = K_1\left(T_{wew} - T_{zew}\right)$$

Stan ustalony (punkt równowagi)

$$T_{wew} = \frac{P_g}{K_1} + T_{zew}$$

$$T_g = \frac{P_g}{K_g} + T_{wew} = \frac{P_g}{K_g} + \frac{P_g}{K_1} + T_{zew}$$

Obliczanie pojemności (C_{vg}, C_{vw})

$$C_v = c_p \rho V$$

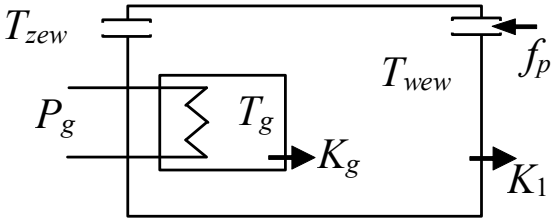
Dane: $P_{gN}, T_{zewN}, T_{wewN}, T_{gN}$

Identyfikacja parametrów (K_g, K_1)

$$K_1 = \frac{P_{gN}}{T_{wewN} - T_{zewN}}$$

$$K_g = \frac{P_{gN}}{T_{gN} - T_{wewN}}$$

Obiekty cieplne



$$\begin{cases} C_{vg}\dot{T}_g(t) = P_g(t) - K_g\left(T_g(t) - T_{wew}(t)\right) \\ C_{vw}\dot{T}_{wew}(t) = K_g\left(T_g(t) - T_{wew}(t)\right) - K_1\left(T_{wew}(t) - T_{zew}(t)\right) + c_{pp}\rho_p f_p(t)T_{zew}(t) - c_{pp}\rho_p f_p(t)T_{wew}(t) \end{cases}$$

$$\begin{cases} C_{vg}\dot{T}_g(t) = P_g(t) - K_g\left(T_g(t) - T_{wew}(t)\right) \\ C_{vw}\dot{T}_{wew}(t) = K_g\left(T_g(t) - T_{wew}(t)\right) - K_1\left(T_{wew}(t) - T_{zew}(t)\right) - c_{pp}\rho_p f_p(t)\left(T_{wew}(t) - T_{wew}(t)\right) \end{cases}$$

wy: T_g, T_{wew}

we: P_g, T_{zew}, f_p

$$\begin{cases} 0 = K_g\left(T_g - T_{wew}\right) - K_1\left(T_{wew} - T_{zew}\right) - c_{pp}\rho_p f_p\left(T_{wew} - T_{zew}\right) \\ 0 = P_g - K_g\left(T_g - T_{wew}\right) \end{cases}$$

$$P_g = K_g\left(T_g - T_{wew}\right) = K_1\left(T_{wew} - T_{zew}\right) + c_{pp}\rho_p f_p\left(T_{wew} - T_{zew}\right)$$

$$T_{wew0} = \frac{P_{g0}}{K_1 + c_{pp}\rho_p f_{p0}} + T_{zew0}$$

$$T_{g0} = \frac{P_{g0}}{K_g} + T_{wew0} = \frac{P_{g0}}{K_g} + \frac{P_{g0}}{K_1 + c_{pp}\rho_p f_p} + T_{zew0}$$

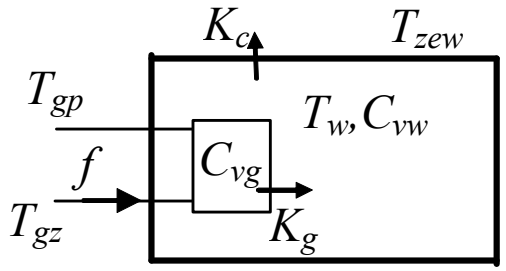
Obliczanie pojemności (C_{vg}, C_{vw})

Dane: $q_{gN}, T_{zewN}, T_{wewN}, T_{gN}$

Identyfikacja parametrów (K_g, K_1)

1) $f_{pN} = V_w/(6 \cdot 60 \cdot 60)$

$$K_g = \frac{P_{g0}}{T_{gN} - T_{wewN}} \qquad K_1 = \frac{P_{gN} - c_{pp}\rho_p f_p\left(T_{wew} - T_{zew}\right)}{T_{wewN} - T_{zewN}}$$



Zakładamy, że $T_g(t) = T_{gp}(t)$

$$\begin{cases} C_{vg}\dot{T}_{gp}(t) = c_{pw}\rho_{pw}f(t)T_{gz}(t) - c_{pw}\rho_{pw}f(t)T_{gp}(t) - K_g\left(T_{gp}(t) - T_{wew}(t)\right) \\ C_{vw}\dot{T}_{wew}(t) = K_g\left(T_{gp}(t) - T_{wew}(t)\right) - K_c\left(T_{wew}(t) - T_{zew}(t)\right) \end{cases}$$

$$\begin{cases} C_{vg}\dot{T}_{gp}(t) = c_{pw}\rho_{pw}f(t)\left(T_{gz}(t) - T_{gp}(t)\right) - K_g\left(T_{gp}(t) - T_{wew}(t)\right) \\ C_{vw}\dot{T}_{wew}(t) = K_g\left(T_{gp}(t) - T_{wew}(t)\right) - K_c\left(T_{wew}(t) - T_{zew}(t)\right) \end{cases}$$

wy: T_{gp}, T_{wew}

we: T_{gz}, T_{zew}, f

$$\begin{cases} 0 = c_{pw}\rho_{pw}f\left(T_{gz} - T_{gp}\right) - K_g\left(T_{gp} - T_{wew}\right) \\ 0 = K_g\left(T_{gp} - T_{wew}\right) - K_c\left(T_{wew} - T_{zew}\right) \end{cases}$$

$$c_{pw}\rho_{pw}f\left(T_{gz} - T_{gp}\right) = K_g\left(T_{gp} - T_{wew}\right) = K_c\left(T_{wew} - T_{zew}\right)$$

$T_{wew} =$

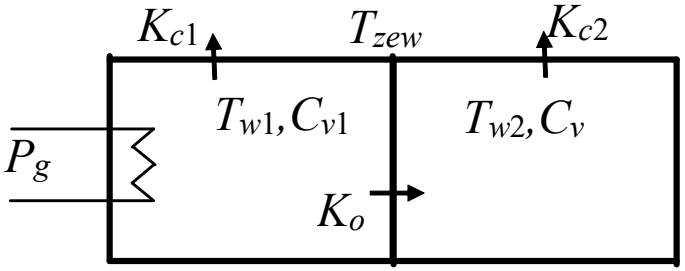
$T_{gp} =$

Identyfikacja parametrów (K_g, K_c)

1) T_{zewN}, T_{wewN}, T_{gzN}, T_{gpN}, f_N

2) T_{zewN}, T_{wewN}, T_{gzN}, T_{gpN}, q_N

$$c_{pw}\rho_{pw}f_N\left(T_{gzN} - T_{gpN}\right) = K_g\left(T_{gpN} - T_{wewN}\right) = K_c\left(T_{wewN} - T_{zewN}\right) = q_N$$



$$\begin{cases} C_{v1}\dot{T}_{w1}(t) = P_g(t) - K_{c1}\left(T_{w1}(t) - T_{zew}(t)\right) - K_o\left(T_{w1}(t) - T_{w2}(t)\right) \\ C_{v2}\dot{T}_{w2}(t) = K_o\left(T_{w1}(t) - T_{w2}(t)\right) - K_{c2}\left(T_{w2}(t) - T_{zew}(t)\right) \end{cases}$$

wy: T_{w1}, T_{w2}

we: P_g, T_{zew}

$$\begin{cases} 0 = P_g - K_{c1}\left(T_{w1} - T_{zew}\right) - K_o\left(T_{w1} - T_{w2}\right) \\ 0 = K_o\left(T_{w1} - T_{w2}\right) - K_{c2}\left(T_{w2} - T_{zew}\right) \end{cases}$$

Identyfikacja parametrów (K_o, K_{c1}, K_{c2})

Dane: P_{gN}, T_{zewN}, T_{w1N}, T_{w2}

$T_{w1} =$

$T_{w2} =$

1) Konstrukcja zewnętrznych ścian jest taka sama,
ale pomieszczenie 2 ma o połowę mniejszą powierzchnię ścian

$K_{c2} = aK_{c1}, a = 0.5$

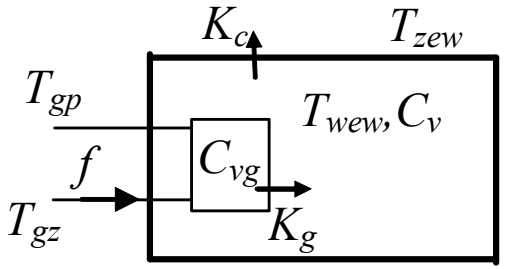
$$K = \frac{kA_w}{a_g}$$

K - w.jednostkowy, W/(mK)
A_w – powierzchnia, m^2
a_g – grubość, m

2) W warunkach nominalnych pomieszczenie z grzejnikiem
60% dostarczonego ciepła traci na zewnątrz

P_g	dostarczane ciepło
$K_{c1}\left(T_{w1} - T_{zew}\right)$	strata na zewnątrz
$K_o\left(T_{w1} - T_{w2}\right)$	strata do pomieszczenia2

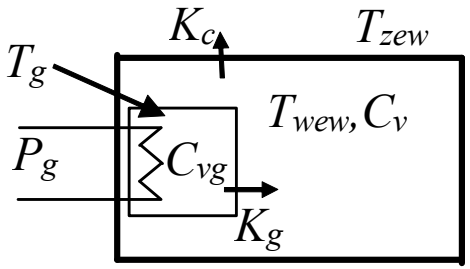
$$\begin{cases} K_{c1}\left(T_{w1} - T_{zew}\right) = 0.6 \cdot P_g \\ K_o\left(T_{w1} - T_{w2}\right) = 0.4 \cdot P_g \end{cases}$$



$$\begin{cases} C_{vg}\dot{T}_{gp}(t) = c_{pw}\rho_{pw}f(t)T_{gz}(t) - c_{pw}\rho_{pw}f(t)T_{gp}(t) - K_g\left(T_{gp}(t) - T_{wew}(t)\right) \\ C_{vw}\dot{T}_{wew}(t) = K_g\left(T_{gp}(t) - T_{wew}(t)\right) - K_c\left(T_{wew}(t) - T_{zew}(t)\right) \end{cases}$$

$$\begin{cases} C_{vg}\dot{T}_{gp}(t) = c_{pw}\rho_{pw}f(t)\left(T_{gz}(t) - T_{gp}(t)\right) - K_g\left(T_{gp}(t) - T_{wew}(t)\right) \\ C_{vw}\dot{T}_{wew}(t) = K_g\left(T_{gp}(t) - T_{wew}(t)\right) - K_c\left(T_{wew}(t) - T_{zew}(t)\right) \end{cases}$$

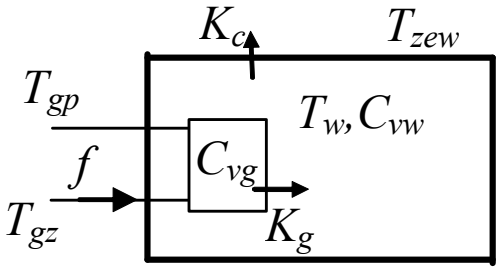
Obiekty cieplne



$$\begin{cases} C_{vg}\dot{T}_{gp}(t) = P_g(t) - K_g\left(T_g(t) - T_{wew}(t)\right) \\ C_{vw}\dot{T}_{wew}(t) = K_g\left(T_g(t) - T_{wew}(t)\right) - K_c\left(T_{wew}(t) - T_{zew}(t)\right) \end{cases}$$

$$T_{wew}(s) = \frac{}{M} q_g(s) + \frac{}{M} T_{zew}(s)$$

$$T_g(s) = \frac{}{M} q_g(s) + \frac{}{M} T_{zew}(s)$$

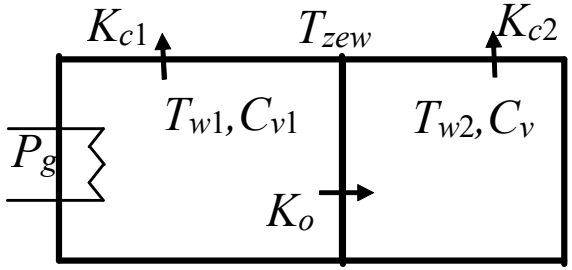


$$\begin{cases} C_{vg}\dot{T}_{gp}(t) = c_{pw}\rho_{pw} f(t)\left(T_{gz}(t) - T_{gp}(t)\right) - K_g\left(T_{gp}(t) - T_{wew}(t)\right) \\ C_{vw}\dot{T}_{wew}(t) = K_g\left(T_{gp}(t) - T_{wew}(t)\right) - K_c\left(T_{wew}(t) - T_{zew}(t)\right) \end{cases}$$

$$f(t) = const$$

$$T_{wew}(s) = \frac{}{M} T_{gz}(s) + \frac{}{M} T_{zew}(s)$$

$$T_{gp}(s) = \frac{}{M} T_{gz}(s) + \frac{}{M} T_{zew}(s)$$



$$\begin{cases} C_{v1}\dot{T}_{w1}(t) = q_g(t) - K_{c1}\left(T_{w1}(t) - T_{zew}(t)\right) - K_o\left(T_{w1}(t) - T_{w2}(t)\right) \\ C_{v2}\dot{T}_{w2}(t) = K_o\left(T_{w1}(t) - T_{w2}(t)\right) - K_{c2}\left(T_{w2}(t) - T_{zew}(t)\right) \end{cases}$$