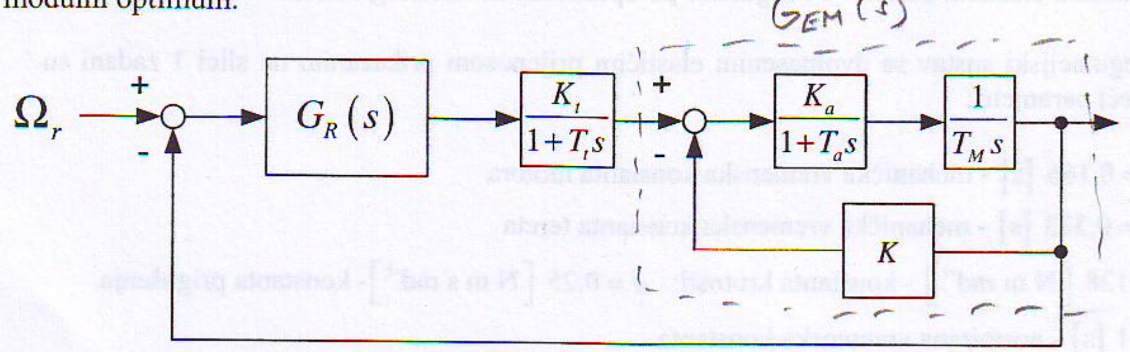
Zadatak 1

Za sustav regulacije na slici 1. potrebno je odrediti parametre PID regulatora koristeći modulni optimum.



Sl. 1. Regulacijski sustav.

Zadano je:

- pojačanje tiristorskog usmjerivača $K_t = 45\left[\frac{V}{V}\right]$
- vremenska konstanta tiristorskog usmjerivača $T_t = 0.005[s]$
- pojačanje kruga armature $K_a = 0.0612\left[\frac{A}{V}\right]$
- vremenska konstanta kruga armature $T_a = 0.0184[s]$
- zaletna vremenska konstanta $T_M = 0.5[s]$
- konstrukcijska konstanta motora $K = 1\left[\frac{Vs}{rad}\right]$

Zadatak 2

Dvomaseni elastični sustav – PI regulator po optimumu dvostrukog odnosa

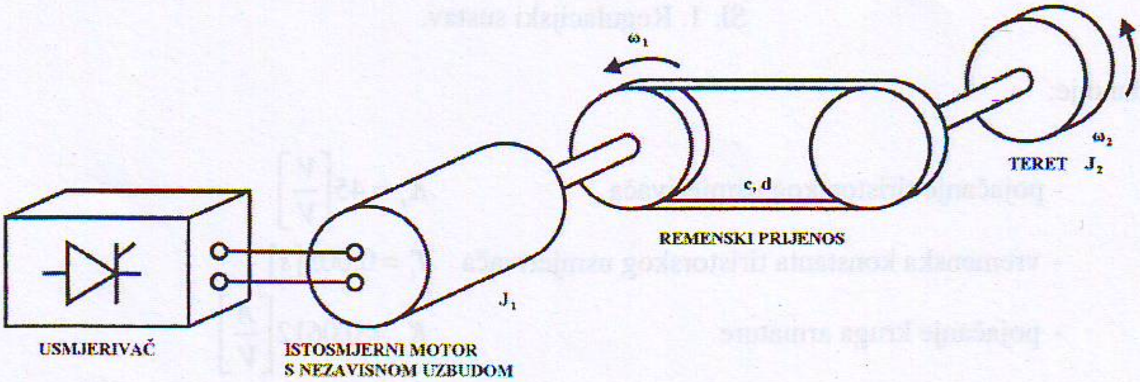
Za regulacijski sustav sa dvomasenim elastičim prijenosom prikazanim na slici 1 zadani su sljedeći parametri:

$T_{M1} = 0.166\ [\mathrm{s}]$ - mehanička vremenska konstanta motora

$T_{M2} = 0.333\ [\mathrm{s}]$ - mehanička vremenska konstanta tereta

$c = 1128\ [\mathrm{N\ m\ rad^{-1}}]$ - konstanta krutosti; $d = 0.25\ [\mathrm{N\ m\ s\ rad^{-1}}]$- konstanta prigušenja

$T_B = 1\ [\mathrm{s}]$ - normirana vremenska konstanta

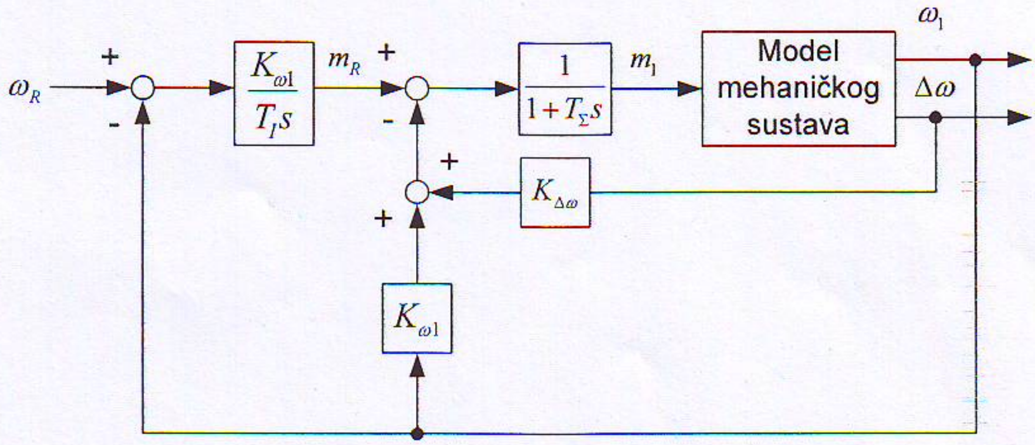


Sl. 1) Skica radnog stroja s remenskim prijenosom.

Potrebno je nacrtati strukturnu blokovsku shemu nadomjesnog kontinuiranog regulacijskog kruga brzine vrtnje s $PI_{\Delta\omega}$ regulatorom po varijablama stanja te odrediti parametre regulatora uz korištenje kriterija dvostrukog odnosa ($D_i = 0.5$), nadomjesnu vremensku konstantu podređenog regulacijskog kruga struje $T_{ei} = 0.01[s]$ i vrijeme diskretizacije $T = 0.001[s]$.

Napomena Nadomjesnu vremensku konstantu zatvorenog kruga odredite koristeći približnu relaciju.

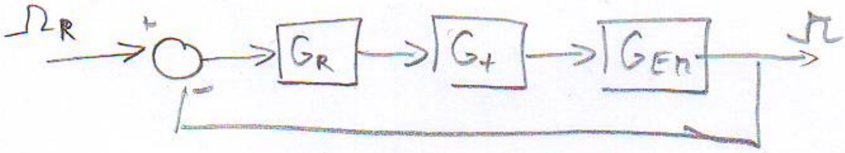
Rješenje:



Sl. 2) Nadomjesna shema kontinuiranog regulacijskog kruga brzine vrtnje s $PI_{\Delta\omega}$ regulatorom.

Zadatak 1

$$G_{EM}(s) = \frac{\frac{K_c}{1+T_a s} \cdot \frac{1}{T_M s}}{1 + \frac{K_a}{1+T_a s} \cdot \frac{1}{T_M s} \cdot K} = \frac{K_a}{T_a T_M s^2 + T_M s + K_a K}$$



$$G_t(s) = \frac{K_t}{1+T_t s}$$

$$G_R(s) = K_R \frac{(1+T_1 s)(1+T_D s)}{T_1 s}$$

$$G_{Cl}(s) = \frac{G_R(s) \cdot G_t(s) \cdot G_{EM}(s)}{1 + G_R(s)\, G_t(s) \cdot G_{EM}(s)}$$

$$= \frac{\overset{b_2}{K_R K_t K_a T_1 T_D} s^2 + \overset{b_1}{K_R K_t K_a (T_1+T_D)} s + \overset{b_0}{K_t K_R K_a}}{\underset{a_4}{T_t T_1 T_a T_M} s^4 + \underset{a_3}{(T_1 T_a T_M + T_t T_1 T_M)} s^3 + \underset{a_2}{(T_1 T_M + T_t T_1 K_a K + K_R K_t K_a T_1 T_D)} s^2 + \underset{a_1}{(K_a K T_1 + K_R K_t K_a T_1 + K_R K_t K_a T_D)} s + \underset{a_0}{K_t K_R K_a}}$$

- prošireni modulni optimum

$$a_i^2 + 2\sum_{j=1}^{i} (-1)^j a_{i-j} a_{i+j} = b_i^2 + 2\sum_{j=1}^{i} (-1)^j b_{i-j} b_{i+j} \qquad \left[i = (\text{red} - 1) \right]$$

- $i=1$

$$a_1^2 - 2a_0 a_2 = b_1^2 - 2b_0 b_2$$

- $i=2$

$$a_2^2 - 2a_1 a_3 + 2a_0 a_4 = b_2^2$$

- $i=3$

$$a_3^2 - 2a_2 a_4 = 0$$

$$T_D = \frac{0{,}359}{K_R}$$

$$K_R = \frac{0{,}023 - 1{,}245\,T_1}{0{,}00025 - 0{,}065\,T_1}$$

$T_{I1} = 0{,}0185$ [s] $\Rightarrow$ $K_{R1} = 0{,}035$ $\Rightarrow$ $T_{D1} = 10{,}257$ [s]

$T_{I2} = \boxed{8{,}368 \text{ [s]}}$ $\Rightarrow$ $\boxed{K_{R2} = 19{,}42}$ $\Rightarrow$ $\boxed{T_{D2} = 0{,}0185 \text{ [s]}}$

$\Downarrow$

iz kvadratne jednadžbe dva rješenja

1

Zadatak 2

$$G_{C1}(s) = \frac{\frac{2\varepsilon_{02}}{\Omega_{02}} s + 1}{a_5 s^5 + a_4 s^4 + a_3 s^3 + a_2 s^2 + a_1 s + \underset{1}{\underset{\parallel}{a_0}}}$$

$$a_1 = T_1 + \frac{2\varepsilon_{02}}{\Omega_{02}}$$

$$a_2 = \frac{T_1 T_{M\Sigma}}{K_{w1}} + 2\frac{\varepsilon_{02} T_1}{\Omega_{02}} + \frac{1}{\Omega_{02}^2}$$

$$a_3 = \frac{T_1 T_{M\Sigma}}{K_{w1}}\left(T_1 + \frac{2\varepsilon}{\Omega_0}\right) + \frac{K_{\Delta w} T_1}{K_{w1}\Omega_{02}^2} + \frac{T_1}{\Omega_{02}^2}$$

$$a_4 = \frac{T_1 T_{M\Sigma}}{K_{w1}}\left(\frac{2\varepsilon T_\Sigma}{\Omega_0} + \frac{1}{\Omega_0^2}\right)$$

$$a_5 = \frac{T_1 T_{M\Sigma} T_\Sigma}{K_{w1}\Omega_0^2}$$

- nadomjesne konstante otvorenog kruga

$T_\Sigma = T + T_{ei} = 0{,}011\,[s]$

$T_e = ?$

$$\tau_M = \frac{T_{M2}}{T_{M1}} = 2 \Rightarrow \frac{5{,}5}{\Omega_0} \geq \tau_e \geq \frac{4}{\Omega_0}$$

$$0{,}0545 \geq T_e \geq 0{,}0396$$

$T_e = 0{,}05\,[s]$

$$T_1 = T_e - 2\frac{\varepsilon_2}{\Omega_{02}} = 0{,}04578\,[s]$$

$$K_{\omega 1} = \frac{T_1 T_{M\Sigma} \Omega_{02}^2}{D_2 T_e^2 \Omega_{02}^2 - 2\varepsilon_2 (T_e \Omega_{02} - 2\varepsilon_2) - 1} = 0,58$$

$$K_{\Delta\omega} = \frac{D_1 D_2^2 T_e^3 \Omega_0 \Omega_{02}^3 - \frac{T_{M\Sigma} T_1 \Omega_{02}^3}{K_{\omega 1}} (T_\Sigma \Omega_0 + 2\varepsilon) - \Omega_0 (T_e \Omega_{02} - 2\varepsilon_2)}{\frac{T_1 \Omega_0 \Omega_{02}}{K_{\omega 1}}}$$

$$= -0,381$$