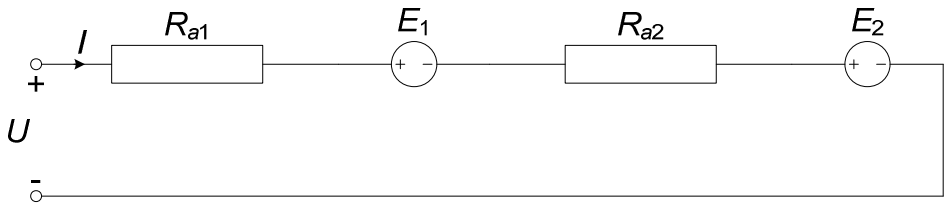
UPRAVLJANJE ELEKTROMOTORNIM POGONIMA
1. međuispit 2008.

1. Zadani podaci su:
M1: 18,4 kW; 220 V; 92,5 A; 1220 r/min; 0,25 Ω
M2: 21,3 kW; 220 V; 107,4 A; 1280 r/min; 0,2 Ω

(a) Nadomjesna shema je:



$$U - I(R_{a1} + R_{a2}) - E_1 - E_2 = 0$$

$$U = I(R_{a1} + R_{a2}) + n(c_{e1} + c_{e2})$$

[vrte se istom brzinom pa je zajednički n]

$$I = \frac{M_1}{c_{m1}} = \frac{M_2}{c_{m2}}$$

[ista je struja armature]

$$M_1 + M_2 = M \rightarrow M_1 = M - M_2$$

[ukupni moment je zbroj pojedinih momenata motora]

$$\frac{M_1}{c_{m1}} = \frac{M_2}{c_{m2}} \rightarrow M_1 c_{m2} = M_2 c_{m1}$$

$$(M - M_2)c_{m2} = M_2 c_{m1} \rightarrow M_2 = M\frac{c_{m2}}{c_{m1} + c_{m2}}$$

$$I = \frac{M_2}{c_{m2}} = \frac{M\frac{c_{m2}}{c_{m1} + c_{m2}}}{c_{m2}} = \frac{M}{c_{m1} + c_{m2}}$$

$$U = I(R_{a1} + R_{a2}) + n(c_{e1} + c_{e2}) = \frac{M(R_{a1} + R_{a2})}{c_{m1} + c_{m2}} + n(c_{e1} + c_{e2})$$

$$n = \frac{U - \frac{M(R_{a1} + R_{a2})}{c_{m1} + c_{m2}}}{c_{e1} + c_{e2}}$$

Konstante c_{e1}, c_{e2}, c_{m1} i c_{m2} se dobiju kao:

$$c_{e1} = \frac{U_{an1} - I_{an1}R_{a1}}{n_{n1}} = \frac{220 - 92{,}5 \cdot 0{,}25}{1220} = 0{,}1614 \ {}^{\text{Vmin}}/_{\text{r}}$$

$$c_{e2} = \frac{U_{an2} - I_{an2}R_{a2}}{n_{n2}} = \frac{220 - 107{,}4 \cdot 0{,}2}{1280} = 0{,}1551 \ {}^{\text{Vmin}}/_{\text{r}}$$

$$c_{m1} = \frac{30c_{e1}}{\pi} = 1{,}541 \ {}^{\text{Nm}}/_{\text{A}}$$

$$c_{m2} = \frac{30c_{e2}}{\pi} = 1{,}481 \ {}^{\text{Nm}}/_{\text{A}}$$

Sada slijedi da je brzina vrtnje jednaka:

$$n = \frac{440 - \frac{240 \cdot (0{,}25 + 0{,}2)}{1{,}541 + 1{,}481}}{0{,}1614 + 0{,}1551} = 1227{,}3 \ {}^{\text{r}}/_{\text{min}}$$

(b) Iz jednadžbe

$$U = \frac{M(R_{a1} + R_{a2})}{c_{m1} + c_{m2}} + n(c_{e1} + c_{e2})$$

slijedi:

$$U = \frac{240 \cdot (0{,}25 + 0{,}2)}{1{,}541 + 1{,}481} + 700 \cdot (0{,}1614 + 0{,}1551) = 257{,}29 \text{ V}$$

(c) Sada je $U = 440$ V i $n = -700 \ {}^{\text{r}}/_{\text{min}}$:

$$U = \frac{M(R_{a1} + R_{a2} + R_p)}{c_{m1} + c_{m2}} + n(c_{e1} + c_{e2}) \rightarrow R_p = \frac{U - n(c_{e1} + c_{e2})}{M}(c_{m1} + c_{m2}) - (R_{a1} + R_{a2})$$

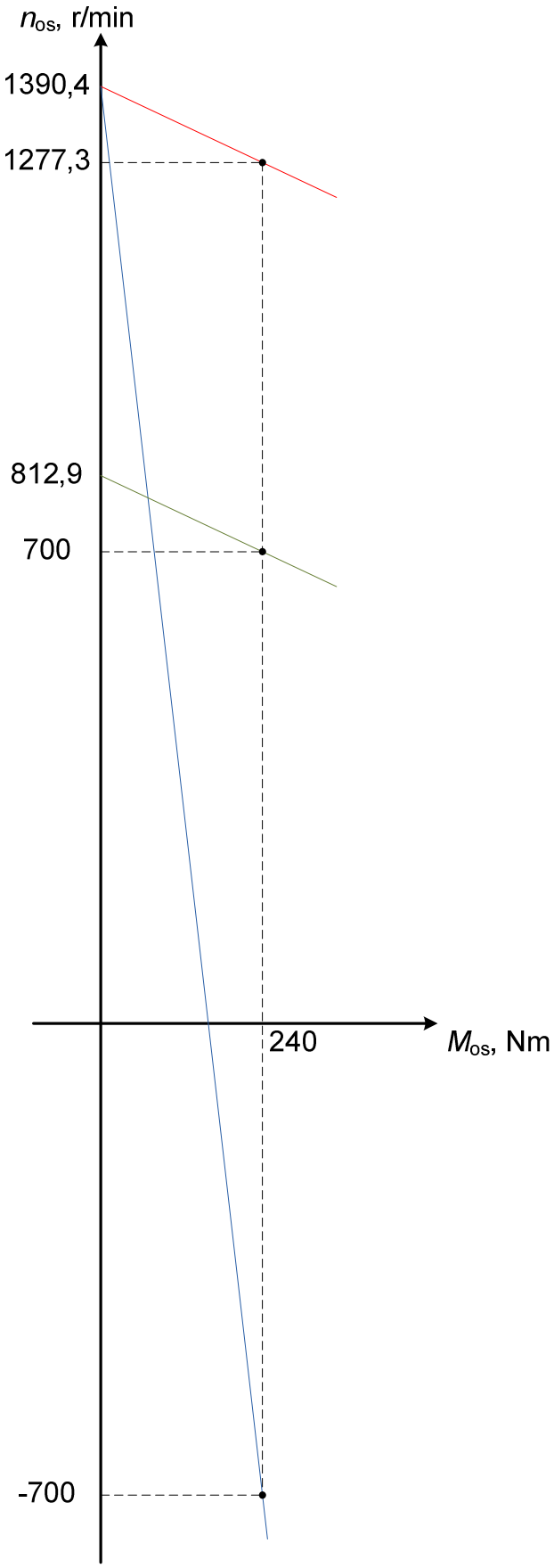
$$R_p = \frac{440 + 700(0{,}1614 + 0{,}1551)}{240}(1{,}541 + 1{,}481) - (0{,}25 + 0{,}2) = 7{,}88 \ \Omega$$

(d) Brzina praznog hoda za **(a)** i **(c)** dio zadatka je:

$$n = \frac{U}{c_{e1} + c_{e2}} = \frac{440}{0{,}1614 + 0{,}1551} = 1390{,}4 \ {}^{\text{r}}/_{\text{min}}$$

Brzina praznog hoda za **(b)** dio zadatka je:

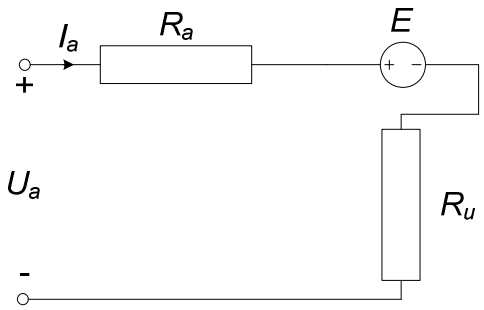
$$n = \frac{U}{c_{e1} + c_{e2}} = \frac{257{,}29}{0{,}1614 + 0{,}1551} = 812{,}9 \ {}^{\text{r}}/_{\text{min}}$$



(a), (b), (c)

2. Zadani podaci su:
$P_n = 2500$ W
$U_{an} = 220$ V
$I_{an} = 15{,}6$ A
$n_n = 1000$ r/min
$R_a = 1{,}3\ \Omega$
$R_u = 0{,}9\ \Omega$
$M_m = kI_a^2$
$M_t = 25$ Nm

Nadomjesna shema je:



(a) Iz nadomjesne sheme vrijedi:

$$U_a - I_a(R_a + R_u) - E = 0$$

$$U_a - I_a(R_a + R_u) - k_E \Phi n = 0$$

$$U_a - I_a(R_a + R_u) - k_E k_\Phi I_a n = 0 \rightarrow k_E k_\Phi = \frac{U_a - I_a(R_a + R_u)}{I_a n}$$

Uzimamo nazivnu radnu točku:

$$k_E k_\Phi = \frac{U_{an} - I_{an}(R_a + R_u)}{I_{an} n_n} = \frac{220 - 15{,}6 \cdot 2{,}2}{15{,}6 \cdot 1000} = 0{,}011903\ {}^{\text{Amin}}/_{\text{r}}$$

$$k_M k_\Phi = \frac{30 k_E k_\Phi}{\pi} = 0{,}11366\ {}^{\text{Nm}}/_{\text{A}^2}$$

Moment je jednak:

$$M = k_M \Phi I_a = k_M k_\Phi I_a^2$$

Slijedi da za zadani teret struja iznosi:

$$I_{at} = \sqrt{\frac{M_t}{k_M k_\Phi}} = \sqrt{\frac{25}{0{,}11366}} = 14{,}83\ \text{A}$$

Sada je:

$$U_{an} - I_{at}(R_a + R_u) - k_E k_\Phi I_{at} n_t = 0 \rightarrow n_t = \frac{U_{an} - I_{at}(R_a + R_u)}{k_E k_\Phi I_{at}}$$

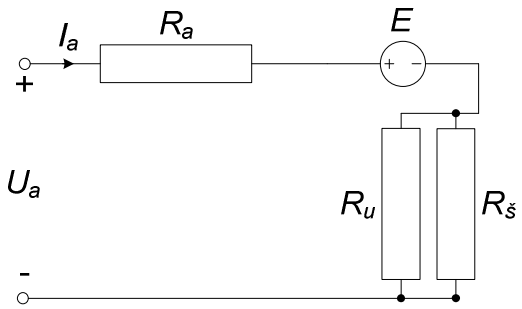
$$n_t = \frac{220 - 14{,}83 \cdot 2{,}2}{0{,}011903 \cdot 14{,}83} = 1061{,}5 \ {}^{\mathrm{r}}/_{\mathrm{min}}$$

(b)

$$U_{an} - I_{at}\left(R_a + R_u + R_p\right) - k_E k_\Phi I_{at} n_t^{'} = 0$$

$$R_p = \frac{U_{an} - k_E k_\Phi I_{at} n_t^{'}}{I_{at}} - R_a - R_u = \frac{220 - 0{,}011903 \cdot 14{,}83 \cdot 500}{14{,}83} - 2{,}2 = 6{,}68\ \Omega$$

(c) Ako se šantira uzbudni namot to znači da se uzbudnom namotu u paralelu dodaje otpor. Nadomjesna shema je:



Za nadomjesnu shemu slijedi:

$$U_{an} - I_a\left(R_a + \frac{R_u R_š}{R_u + R_š}\right) - k_E \Phi n_t^{''} = 0$$

$$\Phi = k_\Phi I_u$$

$$M = k_M \Phi I_a = k_M k_\Phi I_u I_a$$

I_u teče kroz uzbudni namot pa slijedi:

$$I_u = I_a \frac{R_š}{R_u + R_š} = \frac{2}{3} I_a$$

$$M = k_M k_\Phi I_u I_a = \frac{2}{3} k_M k_\Phi I_a^2 \rightarrow I_a = \sqrt{\frac{M}{\frac{2}{3} k_M k_\Phi}} = \sqrt{\frac{25}{\frac{2}{3} \cdot 0{,}11366}} = 18{,}164\ \mathrm{A}$$

$$I_u = 12{,}109\ \mathrm{A}$$

$$n_t^{''} = \frac{U_{an} - I_a\left(R_a + \frac{R_u R_š}{R_u + R_š}\right)}{k_E k_\Phi I_u} = \frac{220 - 18{,}164 \cdot \left(1{,}3 + \frac{0{,}9 \cdot 1{,}8}{0{,}9 + 1{,}8}\right)}{0{,}011903 \cdot 12{,}109} = 1286{,}9 \ {}^{\mathrm{r}}/_{\mathrm{min}}$$

3. Zadani podaci su:
$P_n = 2200$ W
$U_{an} = 110$ V
$I_{an} = 22{,}5$ A
$n_n = 390$ r/min
$R_a = 0{,}7\ \Omega$
$J_M = 0{,}055$ kgm^2
$J_{mz} = 0{,}015$ kgm^2
$J_{b+vz} = J_b + J_{vz} = 1{,}245$ kgm^2
$m_t = 500$ kg
$i = 30$
$\eta_{zp} = 0{,}79$
$\eta_b = 0{,}94$
$r_b = 0{,}5$ m
$U_{DC} = 120$ V

(a)

$$J_{UK} = J_M + J_{mz} + J_{b+vz}\frac{1}{\eta_{zp}}\frac{1}{i^2} + m_t r_b^2 \frac{1}{\eta_{zp}}\frac{1}{\eta_b}\frac{1}{i^2}$$

$$J_{UK} = 0{,}055 + 0{,}015 + 1{,}245 \cdot \frac{1}{0{,}79}\cdot\frac{1}{30^2} + 500 \cdot 0{,}5^2 \cdot \frac{1}{0{,}79}\cdot\frac{1}{0{,}94}\cdot\frac{1}{30^2} = 0{,}25878 \text{ kgm}^2$$

$$P_t = \eta_{zp}\eta_b P_m = \eta_{zp}\eta_b M_m \omega_m$$

$$P_t = m_t g v_t = m_t g \omega_t r_b$$

$$\eta_{zp}\eta_b M_m \omega_m = m_t g \omega_t r_b \rightarrow M_m = \frac{m_t g \omega_t r_b}{\eta_{zp}\eta_b \omega_m} = \frac{m_t g r_b}{\eta_{zp}\eta_b}\frac{\omega_t}{\omega_m} = \frac{m_t g r_b}{\eta_{zp}\eta_b i}$$

$$M_m = \frac{m_t g r_b}{\eta_{zp}\eta_b i} = \frac{500 \cdot 0{,}5 \cdot 9{,}81}{0{,}79 \cdot 0{,}94 \cdot 30} = 110{,}09 \text{ Nm}$$

(b) Radi se o bipolarnoj modulaciji pa je:

$$U_a = (2D - 1)U_{DC} \rightarrow D = \frac{1}{2}\left(1 + \frac{U_a}{U_{DC}}\right)$$

Konstante motora su:

$$c_e = \frac{U_{an} - I_{an}R_a}{n_n} = \frac{110 - 22{,}5 \cdot 0{,}7}{390} = 0{,}24167 \ {}^{\text{Vmin}}/_{\text{r}}$$

$$c_m = \frac{30 c_e}{\pi} = 2{,}30775 \ {}^{\text{Nm}}/_{\text{A}}$$

$$M_m = c_m I_a \rightarrow I_a = \frac{M_m}{c_m} = \frac{110{,}09}{2{,}30775} = 47{,}7 \text{ A}$$

$$n_m = \frac{30\omega_m}{\pi} = \frac{30i\omega_b}{\pi} = \frac{30iv_t}{r_b\pi}$$

$$n_m = \frac{U_a - I_a R_a}{c_e} \rightarrow U_a = n_m c_e + I_a R_a = \frac{30iv_t}{r_b\pi} c_e + I_a R_a$$

$$U_a = \frac{30 \cdot 30 \cdot 0{,}5}{0{,}5 \cdot \pi} \cdot 0{,}24167 + 47{,}7 \cdot 0{,}7 = 102{,}62 \text{ V}$$

$$D = \frac{1}{2}\left(1 + \frac{102{,}62}{120}\right) = 0{,}928$$

(c) Radi se o elektrodinamičkom kočenju pa je $U_a = 0$, dok je smjer struje suprotan (predznak minus):

$$n_m = \frac{U_a - I_a(R_a + R_p)}{c_e} \rightarrow R_p = -\frac{n_m c_e}{I_a} - R_a = -\frac{\frac{30iv_t}{r_b\pi} c_e}{I_a} - R_a$$

$$R_p = -\frac{\frac{30 \cdot 30 \cdot 0{,}5}{0{,}5 \cdot \pi} \cdot 0{,}24167}{-47{,}7} - 0{,}7 = 0{,}75\ \Omega$$