Pogon vratila dizalice za podizanje tereta mase m=500 kg, ostvaruje se pomoću elektromotora i jednostepenog reduktora sa cilindričnim pužnim parom. Za date podatke odrediti:

a) Modul pužnog para ako je zadato međuosno rastojanje a=125mm

b) Snagu, broj obrtaja pogonskog elektromotora kao i stepen iskorišćenja pužnog para, ako je brzina podizanja tereta v=0,4 m/s^2

c) Stepen sigurnosti bokova i podnožja zubaca pužnog zupčanika za radni vek 10000 časova, ako je vratilo puža izrađeno od legura čelika Č 1730, a pužni zupčanik od kalajne bronze PCuSn12
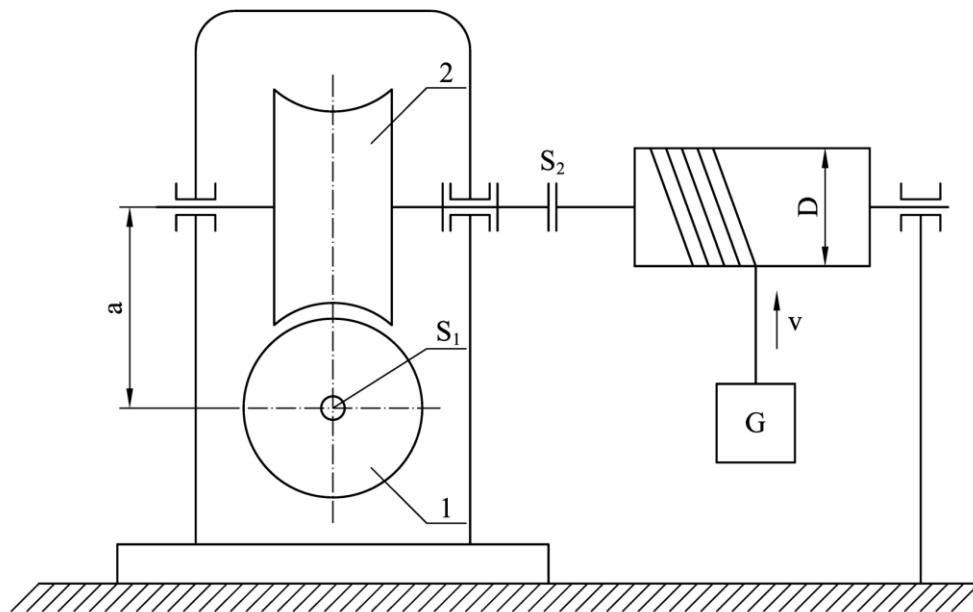
Podaci:

$z_1 = 2$ $x_x = 0,5$

$z_2 = 39$ $a = 125$ mm

$q = 10$ D=155 mm

Rešenje:

a) Izračunavanje modula

$$a = \frac{d_1 + d_2}{2}$$

$$d_1 = d_m + 2x_n m_n$$

$$d_m = q \cdot m_x$$

$$\left.\begin{array}{l} x_n = \dfrac{x_x}{\cos\gamma_m} \\[2mm] m_n = m_x \cdot \cos\gamma_m \end{array}\right\} \Rightarrow x_n m_n = x_x m_x$$

$$d_1 = q \cdot m_x + 2 \cdot x_x m_x = m_x \cdot (q + 2x_x)$$

$$d_2 = m_x \cdot z_2$$

$$a = \frac{1}{2}(q \cdot m_x + 2 \cdot x_x m_x + m_x \cdot z_2) = \frac{m_x}{2}(q + 2x_x + z_2)$$

$$m_x = \frac{2 \cdot a}{q + 2x_x + z_2} = \frac{2 \cdot 125}{10 + 2 \cdot 0,5 + 39} = 5$$

$$q = \frac{z_1}{\tan\gamma_m} \Rightarrow \tan\gamma_m = \frac{z_1}{q} = \frac{2}{10} = 0,2$$

$$\gamma_m = \arctan 0,5 = 11,31°$$

$$m_n = 5 \cdot \cos 11,31 = 4,9029$$

$$d_m = q m_x = 10 \cdot 5 = 50 \text{ mm}$$

$$d_1 = d_m + 2x_x m_x = 50 + 2 \cdot 0,5 \cdot 5 = 55 \text{ mm}$$

$$d_2 = m_x z_2 = 5 \cdot 39 = 195 \text{ mm}$$

b) Snaga, broj obrtaja pogonskog elektromotora i stepen iskorišćenja pužnog para:

$$v = 0,4 \frac{m}{s}$$

$$v = \frac{\omega_2 \cdot D}{2} \Rightarrow \omega_2 = \frac{2 \cdot v}{D} = \frac{2 \cdot 0,4}{0,155} = 5,161 \text{ s}^{-1}$$

$$\omega_2 = 2\pi n_2 \Rightarrow n_2 = \frac{\omega_2}{2\pi} = \frac{5,161}{2 \cdot \pi} = 0,821 \text{ s}^{-1}$$

$$i_{1-2} = \frac{z_2}{z_1} = \frac{39}{2} = 19,5$$

$$n_{EM} = n_1 = n_2 \cdot i = 0,821 \cdot 19,5 = 16 \text{ s}^{-1}$$

$$\eta = \frac{\tan\gamma_m}{\tan(\gamma_m + \rho)}$$

$$\rho = \arctan\mu$$

$$\mu = \mu_0 Y_W Y_G Y_S Y_R$$

$$v_k = \frac{d_m \cdot \pi \cdot n_1}{\cos\gamma_m} = \frac{0,050 \cdot \pi \cdot 16}{\cos 11,31} = 2,56 \ \frac{\text{m}}{\text{s}}$$

Iz tablice 8.16 za brzinu klizanja $v_k = 2,56$ m/s i za mineralno ulje, određujemo koeficijent trenja $\mu_0 = 0,4$.

$Y_W = 1,3$ - uticaj tvrdoće spregnutih materijala

$Y_G = 1,65$ - geometrijski faktor za "ostale profile" puža

$Y_S = \sqrt{\dfrac{100}{a}} = \sqrt{\dfrac{100}{125}} = 0,894$ - uticaj veličine prenosnika

$Y_R = 1$ - uticaj hrapavosti (zanemarujemo zbog nedostatka podataka)

$$\mu = 0,04 \cdot 1,3 \cdot 1,65 \cdot 0,894 \cdot 1 = 0,077$$

$$\rho = \arctan\mu = \arctan 0,077 = 4,386$$

$$\eta = \frac{\tan\gamma_m}{\tan(\gamma_m + \rho)} = \frac{\tan 11,31}{\tan(11,31 + 4,386)} = 0,712$$

$$G = m \cdot g = 500 \cdot 9,81 = 4905 \ \text{N}$$

$$T_2 = G \cdot \frac{D}{2} = 4905 \cdot \frac{0,155}{2} = 380,14 \ \text{Nm}$$

$$P_2 = T_2 \cdot \omega_2 = 380,14 \cdot 5,161 = 1962 \ \text{W}$$

$$P_{EM} = \frac{P_2}{\eta_{1-2}} = \frac{1962}{0,712} = 2755 \ \text{W}$$

Ili preko obrtnog momenta:

$$T_{EM} = \frac{T_2}{i_{1-2} \cdot \eta_{1-2}} = \frac{380,14}{19,5 \cdot 0,712} = 27,38 \ \text{Nm}$$

$$P_{EM} = T_{EM} \cdot \omega_{EM} = 27,38 \cdot 2 \cdot 16 \cdot \pi = 2753 \ \text{W}$$

c) Stepen sigurnosti bokova i podnožja zubaca pužnog zupčanika

Stepen sigurnosti bokova:

$$\sigma_{H2} = Z_E Z_\rho \sqrt{\frac{K_A T_2}{a^3}}$$

$Z_E = 147 \left(\dfrac{\text{N}}{\text{mm}^2}\right)^{0,5}$ - faktor elastičnosti spregnutih materijala

$Z_\rho = 2,05 \cdot \left(\dfrac{d_m}{a}\right)^{-0,34} = 2,05 \cdot \left(\dfrac{50}{125}\right)^{-0,34} = 2,8$ - faktor oblika kontakta zubaca

$K_A = 1,25$ - dinamički faktor (tab. 8.7)

$$\sigma_{H2} = 147 \cdot 2,8 \sqrt{\frac{1,25 \cdot 380,14}{125^3}} = 203 \ \frac{\text{N}}{\text{mm}^2}$$

$$[\sigma_H]_2 = \sigma_{H\lim} \cdot Z_h Z_v Z_S Z_L$$

$$\sigma_{H\lim} = 265 \ \frac{\text{N}}{\text{mm}^2}$$

$$Z_h = \left(\frac{25000}{L_h}\right)^{\frac{1}{6}} = \left(\frac{25000}{10000}\right)^{\frac{1}{6}} = 1,165 \ \text{- faktor veka}$$

$$Z_v = \sqrt{\frac{5}{4 + v_k}} = \sqrt{\frac{5}{4 + 2,56}} = 0,873 \ \text{- faktor uticaja brzine}$$

$$Z_S = \sqrt{\frac{3000}{2900 + a}} = \sqrt{\frac{3000}{2900 + 125}} = 0,996 \ \text{- faktor veličine pužnog para}$$

$Z_L = 1$ - faktor ulja (podmazivanje poliglikol uljem)

$$[\sigma_H]_2 = 265 \cdot 1,165 \cdot 0,873 \cdot 0,996 \cdot 1 = 268,44 \ \frac{\text{N}}{\text{mm}^2}$$

$$S_{H2} = \frac{[\sigma_H]_2}{\sigma_{H2}} = \frac{268,44}{203} = 1,32$$

Stepen sigurnosti u podnožju zubaca:

$$\tau_{F2} = Y \frac{K_A F_{t2}}{b_2 m_n}$$

$Y = 0,55$ - ukupni faktor oblika pužnog venca (za nepohabane zupce)

$$F_{t2} = \frac{2T_2}{d_2} = \frac{2 \cdot 380,44}{0,195} = 3902 \ \text{N}$$

$$b_2 = (0,75...0,8) d_1 = 0,8 \cdot d_1 = 0,8 \cdot 55 = 44$$

$$\tau_{F2} = 0,55 \cdot \frac{1,25 \cdot 3902}{44 \cdot 4,9029} = 12,44$$

$$[\tau_F]_2 = \tau_{F\lim} \cdot Y_{NL}$$

$Y_{NL} = 1$ - za $n_\Sigma > 3 \cdot 10^6$

$$\tau_{F\lim} = 92 \ \frac{\text{N}}{\text{mm}^2} \ \text{(tab. 8.16)}$$

$$[\tau_F]_2 = 92 \ \frac{\text{N}}{\text{mm}^2}$$

$$S_{F2} = \frac{[\tau_F]_2}{\tau_{F2}} = \frac{92}{12,44} = 7,4$$